EVALUATIONS AND SOLUTIONS OF WATER QUALITY IN MAEKONG BASIN USING FUZZY LOGIC AND INDIVIDUAL RANKINGS

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**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(INFORMATION TECHNOLOGY MANAGEMENT)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2015**

Thesis
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was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Mater of Science (Information Technology Management)
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ACKNOWLEDGEMENTS

This thesis would not be success without supports, advices and encouragements from many people. I would like to express my gratitude to my advisor Asst. Prof. Adisorn Leelasantitham, Asst. Prof. Supaporn Kiattisin and Lect. Sotarat Thammaboosadee. They was recommended me on this thesis of this topic and knowledge of fuzzy logic and using tools. They was gave me a good advices and taught me about how to thinking process.

The indispensable group was my family and my friend who always stays beside and encourage me when I was under pressure and discouraged. Even they do not know deeply in this topic, but they tend to support me as much as possible. Finally, I gratitude Assoc. Prof. Orapin Aeimsiri, Asst. Prof. Bunlur Emaruchi and Lect. sanchai sutipanwihan who ranking for selection troubleshooting water quality of research me it succeed this thesis.

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ABSTACT

This thesis presents a model to create rules in order to divide four criteria (i.e. good, medium, bad and very bad) of water quality from 5 water quality indexes as follows: BOD, DO, FCB, TCB and NH_3. The data sets are collected from the Maekong basin from 9 provinces in Thailand. They have been used for more than 100 sets from 41 sampling stations. In this study, a methodology based on fuzzy logic to assess water quality is proposed. The result shows that an accuracy is 77.95%. After that, if the water quality is bad/very bad level, solutions of improving water quality will be found through the use of group decision making based on analysis of individual rankings method from many experts in order to obtain the appropriate solutions of water quality and good performance.

KEY WORDS: WATER QUALITY/ EVALUATION LEVELS OF WATER QUALITY FUZZY LOGIC/ / GROUP DECISION/ INDIVIDUAL RANKING

72 pages

การประเมินและแก้ไขคุณภาพน้ำในลุ่มน้ำแม่กลองโดยใช้ตรรกศาสตร์คลุมเครือและการจัดลำดับรายบุคคล

EVALUATIONS AND SOLUTIONS OF WATER QUALITY IN MAEKONG BASIN USING FUZZY LOGIC AND INDIVIDUAL RANKINGS

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บทคัดย่อ

วิทยานิพนธ์เล่มนี้ได้นำเสนอการสร้างกฎเพื่อแบ่งเกณฑ์คุณภาพน้ำจาก 5 ดัชนีคุณภาพน้ำ คือ BOD DO FCB TCB และ NH_3 ซึ่งแบ่งเกณฑ์ออกเป็น 4 ระดับ คือ ดี พอใช้ เสื่อมโทรม และเสื่อมโทรมมาก โดยชุดข้อมูลได้รวบรวมจากลุ่มน้ำแม่กลองใน 9 จังหวัด ซึ่งใช้ข้อมูลมากกว่า 100 ชุด จาก 41 สถานี โดยใช้วิธีตรรกศาสตร์คลุมเครือในการประเมินคุณภาพน้ำ ซึ่งผลลัพธ์ที่ได้จากวิธีตรรกศาสตร์คลุมเครือมีค่าความแม่นยำร้อยละ 77.95 จากนั้นนำระดับคุณภาพน้ำมาวิเคราะห์ หากคุณภาพน้ำเสื่อมโทรมหรือเสื่อมโทรมมาก จะต้องหาวิธีการแก้ไขปัญหาคุณภาพน้ำโดยใช้วิธีการตัดสินใจกลุ่มจากการจัดลำดับของผู้เชี่ยวชาญแต่ละคนเพื่อให้ได้วิธีการแก้ไขปัญหาคุณภาพน้ำที่เหมาะสมและมีประสิทธิภาพ

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CHAPTER I
INTRODUCTION

1.1 Background and significance of the problems

All natural resources, water is the most precious and essential. The important factor for survival of all beings in terms of consumption system should be concerned. Water after using would be released to water reservoir. Again, this mentioned water circulation system causes water pollution problems. How are we could know water level quality and if the water causes harmful effect to consumer or not? The amount of pollutants on the health of the water source ecosystem can be very attend, depending on the social characteristics and economic of the riverside society benefit with the water. In Thailand, there are 25 basins including 3 basins of central region, as follows: Chaopraya, Thachin and Maekong. The results of monitoring and surveillance of water quality of Chaopraya, Thachin and Maekong basin in 2012 were found very bad water quality with 24%, 26% and 29.17%, respectively [1]-[3]. In this thesis, we study Maekong basin. This is because Maekong basin has several problems of poor water quality with high rank in Thailand. Especially, the sources of wastewater are as follows the community, industries, agriculture, and livestock farms. From statistics in 2008-2012, it was found that the good water quality was declining, whereas the bad water quality was increasing every year, as shown in Figure1.1.

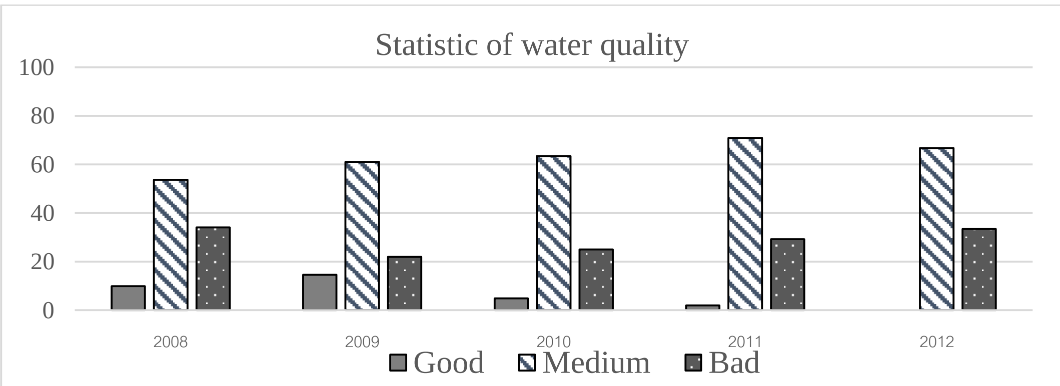


Figure 1.1 Water quality of Maekong basin in 2008-2012 [1].

Generally, The Water Quality Indicators (WQI) used to evaluate water quality. WQI is got by multiplication of the specific weight factor by a reasonable quality-value for each indexes. The WQI consists of 9 parameters as follows: biochemical oxygen demand (BOD), dissolved oxygen (DO), faecal coliforms bacteria (FCB), nitrates (NO3), acid-base (pH), total solids (TS), phosphate, turbidity and temperature, which the score of all parameters originate the questionnaire of the experts, but parameter as above inapplicable in Thailand. This is because some parameter not defined in standard of ground water in Thailand. Therefore, in the present, we study 5 parameters, as follows: BOD, DO, FCB, TCB and NH3.

Dissolved Oxygen (DO) is quantity of gaseous oxygen dissolved present in water. It is an important parameter in evaluating water quality because it be influential on the life living in a water source. DO level that is too low or too high can danger aqueous organisms and effect water quality [4].

Biochemical Oxygen Demand (BOD) is amount of dissolved oxygen needed by aerobic biological organisms in a water source to collapse organic matter present in a given water example at exact temperature over respective time. It is used a display of the organic quality in a body of water [5].

Fecal Coliform Bacteria (FCB) in aqueous environments may present that the water source has been tarnished with the fecal matter of other animals or humans. FCB can enter water source through direct release of waste from human sewage, from birds and mammals, from storm runoff and agricultural [6].

Total coliforms Bacteria (TCB) are group of bacteria normally found in environment, for sample in soil or vegetation, TCB are not cause illness, but represent your water supply might weakened to pollution by more dangerous microorganisms [7].

Ammoniacal nitrogen (NH_3) is a measure for quantity of ammonia, a toxic pollutant frequently found in sewage products and in landfill leachate, such as waste water, and other liquid organic waste products. It is used as an indicator of the health of water in the body naturally such as water reservoirs, lakes and rivers [8]. Five parameters can explain overview of water quality in water source to be acceptable. Which specification of the many experts engender ambiguity of criterion, because each expert specified value of criterion water quality are not same, so fuzzy logic is used to determine the criterion water quality.

After taking the criterion of water quality, if water quality is not good, we must find out the alternative solutions of water quality. With several troubleshooting, if the selective solution by only one expert might not be the best solution, therefore the solution taken by many experts decision is proposed. This is because persons have differences in ideas, values and knowledge. Therefore, we propose the use of group decision of individual rankings multi-criteria method in order to obtain the appropriate solution of water quality and performance from experts.

1.2 Research objectives

1.2.1 To study of classification criteria for water quality.

1.2.2 To create fuzzy rule for divide criterion water quality.

1.2.3 To choose solution of water quality appropriateness and performance from experts.

1.3 Delimitation of the research

In Thailand, with water quality indicators of BOD, DO, FCB, TCB and NH_3 in the Maekong basin, the data sets are collected from 9 provinces including Tak, Uthaithani, Kanchanaburi, Suphanburi, Nakhonpathom, Ratchaburi, Samutsongkram, Samutsakron and Petchaburi. The data sets have been used from more than 100 sets from 41 sampling stations, which average each year since 2007-2012.

1.4 Expected outcomes and benefits

1.4.1 Model for a rule creation divided criterion water quality

1.4.2 Levels of Water Quality with ambiguity

1.4.3 Clarity of criterion water quality from the experts

1.4.4 Description to overview of water quality in river

1.4.5 The alternative for solution of water quality appropriateness and performance from experts.

CHAPTER II
LITERATURE REVIEWS AND RELATED THEORIES

2.1 Literature reviews

2.1.1 Fuzzy Logic for evaluation of water quality

In 2007, Y. Icaga [9] presented fuzzy evaluation of water quality classification. These classes were combined with fuzzy logic to combine with fuzzy logic each parameter to result score of levels water quality was obtained to represent quality classes of all parameters in order to make water quality assessment more comprehensible especially in public consideration. In 2012 H. Gharibi et al [10] presented a novel approach in water quality assessment based on fuzzy logic. The fuzzy-based water quality index we developed produces more stringent results than those of the WQI due to the distinct computational method applied, as well as inclusion of a higher number of parameters, all of which are critical for assessment of water quality. D. Scannapieco et al [11] presented river water quality assessment: A comparison of binary- and fuzzy logic-based approaches. The aim of the present study is to show how fuzzy analysis can be implemented when running a water quality assessment, and then focus on a relevant case study. Fuzzy logic approach is studied in order to manage the subjectivity of the analysis, in which examined indicators are classified after data fuzzification and a subsequent defuzzification. A potential optimization of water quality assessment would then reduce sampling frequencies when downward or steady-state trends are found during monitoring campaigns.

2.1.2 Individual rankings

In 1985, J. P. Brands and Ph. Vincke [12] presented a preference ranking oranisation method. The individual rankings are constructed through the use of the PROMETHEE II method, where each decision maker defined the weights of the criteria and the preference functions for each criterion. PROMETHEE II method, this method is appropriate for the problematic of ranking and is flexible, and thus allows each decision maker to assign a different relative importance to criteria. This aspect makes the PROMETHEE method a very suitable application for this situation. Another advantage of PROMETHEE is related to the fact that the decision makers find it easy to understand the concepts and parameters inherent in the method, which makes preference modeling simpler and, consequently, increases the efficiency of applying the method. Without this multicriteria analysis prior to aggregate the ordinal information, the members of the group could lose a very important phase in a group decision process, which are the constructive process and the gain of knowledge about the problem. Applying the PROMETHEE method is easier to find greater clarity in how the alternatives are evaluated and to understand better the problem. In 2007, D.C. Morais and A.T. de Almeida [13] proposed Group decision-making for leakage management. That is multicriteria group decision model based on PROMETHEE GDSS procedure and PROMETHEEV method, has the potential of being a decisive positive contribution to the process of the development of a leakage management strategy, putting together the preferences of different groups of influence, including criteria relying on interdisciplinary principles, such as technical, economic, environmental aspects and social perception. It is important to notice that, in spite of the group decision-making model presented here was addressed for the problem of leakage management strategy; the use of the model is not restricted to this problematic context. The proposed model can also be used in other problems that need the involvement of various decision-makers, as well as the integration of the public participation. The connection of opinions of each member involved becomes the decision process more transparent than when it is analyzed in a closed way, without the society participation. When people realize the transparency, the changes are better accepted and the credibility is guaranteed. In 2010, V.B.S. Silva [14] presented A Multicriteria Group Decision Model to Support Watershed Committees in Brazil. Since the decisions will usually have great impact on the activities of the state, city and private sectors, the possibility of conflict is very high. Thus, the analyst must be as impartial as possible in order to establish a relationship of trust among the group. In 2012, Danielle C. Morais and Adiel Teixeira de Almeida [15] presented group decision making on water resources based on analysis of individual rankings. The method allows for the alternatives for solution that for certain problem tube aimed at, which ensures that most the decision makers are satisfied with the final result found. This method can be used to deal with many kinds of group decision making problems.

2.2 Related theories

2.2.1 Water quality

Water quality means to the physical, radiological, biological and chemical unique of water. It is a measure of water relative to the requirements of one or more human need and life species. The generally used to evaluate water quality relative to security of health of ecosystems and human contact.

The goals of water quality include

1) To encourage people to have better health.

2) To promote and preserve the aquatic ecosystem.

3) Support the use of water resources with water quality control standards.

4) Conservation and Improvement Water quality of water source.

5) Prevent or minimize pollution from point sources.

2.2.2 Water Quality Index (WQI)

The WQI have number that appropriate to overview of water quality a certain time and location based on many WQI. The purpose of the index is to turn the complex water quality in the data are understood and used by the public. The grade of water quality index is a problem of debate scientists. The single numbers cannot indicate the all story of water quality. The other water quality indexes that are not consisted in this index. These indexes are not intended only to aquatic regulations or human health. Water index based on some so significant parameter to supply a simple indicator of water quality. The problem comes from the region [16].

2.2.2.1 Acidity

Acidity of water is a capability to respond with a strong base to designate pH. Acidity is a gauge of a total characteristic of water. It can be explain in terms of particular substances, when the chemical composition of example is known.

2.2.2.2 Alkalinity

The Alkalinity or the buffering capacity of a stream refers to how well it can solve the pollution, acid and alkali resist changes in pH measures the amount of alkali in the water as follows: bicarbonates, hydroxides and carbonates. These compounds are a natural buffer to remove excess ions and hydrogen.

2.2.2.3 BOD

BOD or Biochemical Oxygen Demand is amount of dissolved oxygen needed by aerobic biological organisms in a water source to collapse organic substance present in a given water example at exact heat during that time. It is used a display of the organic quality in a body of water [5].

2.2.2.4 CBOD

CBOD or Carbonaceous biochemical oxygen demand measures the quantity of require of oxidized by carbon. CBOD is a part of the BOD that not included the nitrogenous oxygen demand by the addition of nitrogen inhibitors during the analysis.

2.2.2.5 COD

COD or Chemical oxygen demand is used a gauge of the oxygen equal of the organic substance weight of an example that are weakened to oxidation with forceful chemical oxidant. It is examples from a particular source, COD can observe to organic matter, organic carbon or BOD. This test is helpful for control and monitoring since relationship has been confirmed. Ammonia present each in liberated or sewage of nitrogen-containing organic substance, which non-oxidized in the absence of important contemplation to free chloride ions.

2.2.2.6 Conductivity

Conductivity is a measure of how well water can pass an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum. The presence of these substances increases the conductivity of a body of water. Organic substances like oil, alcohol, and sugar do not conduct electricity very well, and thus have a low conductivity in water. Inorganic dissolved solids are essential ingredients for aquatic life. They regulate the flow of water in and out of organisms' cells and are building blocks of the molecules necessary for life. A high concentration of dissolved solids, however, can cause water balance problems for aquatic organisms and decrease dissolved oxygen levels.

2.2.2.7 Dissolved Oxygen

The amount of Dissolved Oxygen or DO in water is expressed as a concentration. A concentration is the amount of in weight of a particular substance per a given volume of liquid. The DO concentration in a stream is the mass of the oxygen gas present, in milligrams per liter of water. Milligrams per liter, or mg/L, can also be expressed as parts per million, or ppm. The concentration of dissolved oxygen in a stream is affected by many factors:

Oxygen concentrations vary with the volume and velocity of water flowing in a stream. Faster flowing white water areas tend to be more oxygen rich because more oxygen enters the water from the atmosphere in those areas than in slower, stagnant areas.

Aquatic Plants: The presence of aquatic plants in a stream affects the dissolved oxygen concentration. Green plants release oxygen into the water during photosynthesis. Photosynthesis occurs during the day when the sun is out and ceases at night. Thus in streams with significant populations of algae and other aquatic plants, the dissolved oxygen concentration may fluctuated daily, reaching its highest levels in the late afternoon. Because plants, like animals, also take in oxygen, dissolved oxygen levels may drop significantly by early morning.

Human Activities Affecting DO: Removal of riparian vegetation may lower oxygen concentrations due to increased water temperature resulting from a lack of canopy shade and increased suspended solids resulting from erosion of bare soil.

Dissolved or suspended solids: Oxygen is also more easily dissolved into water with low levels of dissolved or suspended solids.

Organic wastes and other nutrient inputs from sewage and industrial discharges, septic tanks and agricultural and urban runoff can result in decreased oxygen levels. Nutrient input often lead to excessive algal growth. When the algae die, the organic matter is decomposed by bacteria. Bacterial decomposition consumes a great deal of oxygen.

Typical urban human activities may lower oxygen concentrations. Runoff from impervious surfaces bearing salts, sediments and other pollutants increases the amount of suspended and dissolved solids in stream water [4].

2.2.2.8 Fecal Coliform

Human and animal wastes carried to stream systems are sources of pathogenic or disease-causing, bacteria and viruses. The disease causing organisms are accompanied by other common types of nonpathogenic bacteria found in animal intestines, such as enterococci bacteria, fecal coliform bacteria and E. coli bacteria or escherichia coli. Enterococci bacteria, fecal coliform, and E. coli bacteria are not usually disease-causing agents themselves. However, high concentrations suggest the presence of disease-causing organisms. Enterococci bacteria, fecal coliform, and E. coli bacteria are used as indicator organisms; they indicated the probability of finding pathogenic organisms in a stream. To measure indicator bacteria, water samples must be collected in sterilized containers. The samples are forced through a filter and incubated at a specific temperature for a certain amount of time. The resulting colonies that form during incubation are recorded and counted as the number of colony producing units per 100 mL of water.

2.2.2.9 Hardness

Hardness is often used as an assessment of the quality of water supplies. The hardness of a water is dominated by the content of calcium and magnesium salts, largely combined with carbonate and bicarbonate and with chlorides, sulfates and other anions of mineral acids.

2.2.2.10 Metals

The effects of metals in water and wastewater range from beneficial through troublesome to dangerously toxic. Some metals are essential, others may adversely affect water consumers, wastewater treatment systems, and receiving waters. Some metals may be either beneficial or toxic, depending on concentration. The primary mechanism for toxicity to organisms that live in the water column is by absorption to or uptake across the gills: this physiological process requires metal to be in a dissolved form. This is not to say that particulate metal is nontoxic, only that particulate metal appears to exhibit substantially less toxicity than does dissolved metal.

Dissolved: Those metals of an unacidified sample that pass through a 0.45 micrometer membrane filter and is thought to better represent the bioavailable fraction of metal in the water column than total recoverable metal.

Recoverable: Those metals that are not tightly bound and biologically available to aquatic organisms

Total: Includes all metals, inorganically and organically bound, both particulate and dissolved. Will give unrealistic high value of those metals that are biological available to aquatic organisms.

Not all metals are acutely toxic in small concentrations. The "heavy metals" include zinc or Zn, copper or Cu, iron, mercury, or Hg, Fe cadmium or Cd and lead or Pb, and the most toxic to aquatic organisms. Some water quality characteristics which affect metal toxicity include alkalinity, temperature, pH, suspended solids, hardness, redox potential and dissolved organic carbon. Metals can bind to many inorganic and organic compounds which reduces the toxicity of the metal.

2.2.2.11 Nitrogen

Nitrogen is important to all life. Nitrogen in the atmosphere or in the soil can go through many complex chemical and biological changes. It can be combined into living and non-living material and return back to the soil or air in a continuing cycle called the nitrogen cycle. Nitrogen occurs in natural waters in various forms, including nitrite or NO_2, nitrate or NO_3, and ammonia or NH_3. Nitrite is less stable and usually present in much lower amounts than nitrate. Nitrate is the most common form tested. Test results are usually expressed as nitrate-nitrogen or NO_3-N, which simply means nitrogen in the form of nitrate. Ammonia is the least stable form of nitrogen and thus difficult to measure accurately.

2.2.2.11.1 Nitrogen as Ammonia

Ammonia or NH_3 is one of the most important pollutants in the aquatic environment because of its relatively highly toxic nature and its ubiquity in surface water systems. It is discharged in large quantities in municipal, industrial and agricultural waste waters. In aqueous solutions, ammonia assumes two chemical forms: NH_3 - unionized (toxic) and NH_4^+ - ionized (nontoxic). The relative concentration of ionized and unionized ammonia in a given ammonia solution are principally a function of temperature, pH and ionic strength of the aqueous solution: Total NH_3: Total ammonia is the sum of the NH_3 and NH_4^+.

2.2.2.11.2 Nitrogen as Nitrite

Nitrite or NO_2- is extremely toxic to aquatic life. However, is usually present only in trace quantity in most natural freshwater systems because it is rapidly oxidized to nitrate. In wastewater treatment plants using nitrification process to convert ammonia to nitrate, the process may be impeded, causing discharge of nitrite at elevated concentrations into receiving waters. The conversion process is affected by pH, including temperature, dissolved oxygen and several factors, number of nitrifying bacteria and presence of inhibiting coTmpounds. Total ammonia in sewage treatment systems consists of NH_3- plus NH_4^+. If pH of the solution increases either naturally or by addition of a base, the concentration of unionized NH3 increases. It impedes the conversion of nitrite to nitrate, causing nitrite to accumulate. When the pH decreases, as NO_2 and NH_4^+ are oxidized an increase in HNO_2 concentration occurs. Nitrous acid inhibits both nitrosomanads bacteria and nitrobacteria, this inhibition can result in an increase in nitrite. As pH increases the toxicity in terms of NO_2 as N decreases and the toxicity in terms of HNO_2 as N increases.

2.2.2.11.3 Nitrogen as Nitrate

Nitrate or NO_3-: Generally occurs in trace quantities in surface water. It is the essential nutrient for many photosynthetic autotrophs and has been identified as the growth limit nutrient. It is only found in small amounts in fresh domestic sewage, but in effluent of nitrifying biological treatment plants, nitrate may be found in concentrations up to 30 mg. nitrate as nitrogen/L. Nitrate is a less serious environmental problem, it can be found in relatively high concentrations where it is relatively nontoxic to aquatic organisms. When nitrate concentrations become excessive, however, and other essential nutrient factors are present, eutrophication and associated algal blooms can be become a problem.

2.2.2.11.4 Nitrogen as Total Kjeldahl

Organic nitrogen and ammonia can be determined together and have been referred to as Kjeldahl nitrogen or TKN, a term that reflects the technique used in their definition.

2.2.2.11.5 Nitrogen, Organic

Organic Nitrogen: It is the byproduct of living organisms. It consists such natural materials as peptides and proteins, urea and nucleic acids, and numerous synthetic organic materials. Typical organic nitrogen concentrations differ from a few hundred micrograms per liter in some lakes to more than 20 mg/L in raw sewage.

2.2.2.12 Phosphorus

Phosphorus is often the limiting nutrient for plant growth, meaning it is in short supply relative to nitrogen. Phosphorus usually happens in nature as phosphate, which is a phosphorous atom combined with four oxygen atoms or PO_4^{3-}. Phosphate that is bound to plant or animal tissue is known as organic phosphate. Phosphate that is not associated with organic material is known as inorganic phosphate. Both forms are present in aquatic systems and may be either dissolved in water or suspended (attached to particles in the water column). Inorganic phosphate is often referred to as reactive phosphorous or orthophosphate. It is the form most readily available to plants and thus may be the most useful indicator of immediate potential problems with excessive plant and algal growth. Testing for total phosphorous (both organic phosphate and inorganic) provides you with a more complete measure of all the phosphorus that is actually in the water.

2.2.2.13 pH

pH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or basic, the H^+ or OH^- ion activity may disrupt aquatic organisms biochemical reactions by either harming or killing the stream organisms. pH is expressed in a scale with ranges from 1 to 14. A solution with a pH less than 7 has more H^+ activity than OH^- and is considered acidic. A solution with a pH value greater than 7 has more OH^- activity than H^+ and is considered basic. The pH scale is logarithmic, meaning that as you go up and down the scale, the values change in factors of ten. A one-point pH change indicates the strength of the base or acid has decreased or increased tenfold. Streams generally have a pH values ranging between 6 to 9, depending upon the presence of dissolved substances that come from soils, bedrock and other materials in the watershed. pH can change the aspects of water chemistry. For sample, as pH increases, smaller amounts of ammonia are needed to reach a level that is toxic to fish. As pH decreases, the concentration of metal may increase because higher acidity increases their ability to be dissolved from sediments into the water.

2.2.2.14 Total Solids

Total Solids is a measure of the dissolved and suspended solids in a body of water. It is related to both conductivity and turbidity. To measure total dissolved and suspended solids, for example of water is placed in a drying oven to evaporate the water, leaving the solids. To measure dissolved solids, the example is filtered before it is weighed and dried. To calculate the suspended solids, the weight of the dissolved solids is subtracted from the total solids.

2.2.2.15 Temperature

Water Temperature is a controlling factor for aquatic life. It controls the rate of metabolic activities, reproductive activities and therefore, life cycles.

If stream temperatures decrease, increase or fluctuate too widely, metabolic activities may speed up, slow down, malfunction, or stop altogether. There are many factors that can influence the stream temperature. Water temperatures can fluctuate even hourly, daily, and seasonally especially in smaller sized streams. Spring discharges and overhanging canopy of stream vegetation provides shade and helps buffer the effects of temperature changes. Water temperature is also influenced by the velocity and quantity of stream flow. The sun has much less effect in warming the waters of streams with swifter and greater flows than of streams with smaller, slower flows. Temperature affects the concentration of dissolved oxygen in a water body. Oxygen is more easily dissolved in cold water.

2.2.2.16 Turbidity

Turbidity is a measure of the cloudiness of water. Cloudiness is caused by plankton (microscopic plants and animals) and suspended solids (mainly soil particles) that are suspended in the water column. Moderately low levels of turbidity may indicate a healthy, well-functioning ecosystem, with moderate amounts of plankton present to fuel the fuel the food chain. However, higher levels of turbidity pose several problems for stream systems. Turbidity blocks out the light needed by submerged aquatic vegetation. It also can raise surface water temperatures above normal because suspended particles near the surface facilitate the absorption of heat from sunlight. Suspended soil particles may carry pesticides, nutrients and other pollutants throughout a stream system, and they can bury eggs and benthic critters when they settle. Turbid waters may also be low in dissolved oxygen. High turbidity may result from sediment bearing runoff or nutrients inputs that cause plankton blooms [17].

2.2.3 Evaluation of water quality

Generally, evaluation of water quality using calculation score from water quality index(WQI) nine parameter follows : biochemical oxygen demand (BOD), dissolved oxygen (DO), faecal coliforms bacteria (FCB), nitrates (NO3), acid-base (pH), total solids (TS), phosphate, turbidity and temperature, which score extracted equation 1 [22].

$$WQI_9 = \sqrt[9]{[BOD][DO][FCB][NO_3][pH][TEMP][TS][PO_4^{-3}][TUR]}. \quad (2.1)$$

Where, WQI_9 = Total score of the water quality index;
TEMP = Temperature;
pH = acid-base;
DO = Dissolved Oxygen;
NO_3 = Nitrogen as Nitrate;
PO_4^{3-} = Phosphorus;
TUR = Turbidity;
TS = Total Solids;
BOD = Biological Oxygen Demand;
FCB = Fecal Coliform.

Table 2.1 Score range of WQI_9 with criterion of water quality index.

Criterion of water quality index	Score WQI_9
Very good	91-100
Good	71-90
Medium	61-70
Bad	31-60
Very bad	0-30

In Thailand, since 1998 pollution control department brought WQI for evaluation of water quality the water source for report levels water quality yearly. Score of WQI had value 0 to 100, if score WQI have low, water quality have bad criterion. If score WQI have low, water quality have good criterion. which the score of all parameters originate the questionnaire of the experts, but parameter as above inapplicable in Thailand because some parameter not defined in standard of ground water in Thailand, Then WQI in Thailand exchange from 9 parameters to 5 parameters as follows: Biochemical oxygen demand (BOD), Dissolved Oxygen (DO), Fecal Coliform Bacteria (FCB), Total coliforms Bacteria (TCB) and Ammoniacal nitrogen (NH3).

2.2.4 Algorithm for create model

2.2.4.1 Algorithm in the Pollution control department

Since the score of water quality originate the questionnaire of the experts, which experts take score to concentration of each parameter and evaluation levels of water quality each parameter, then calculated the total score of the water quality by calculation of water quality in Thailand currently used the equation 2 [23].

$$WQI_5 = \frac{DO + BOD + FCB + TCB + NH_3}{5} - PS. \qquad (2.2)$$

Where,

$$PS = \begin{cases} 0\,; if\ levels\ of\ water\ quality\ each\ parameter\ equal \\ 10\,; if\ levels\ of\ water\ quality\ each\ parameter\ different\ 1\ level \\ 15\,; if\ levels\ of\ water\ quality\ each\ parameter\ different\ 2\ levels \\ 20\,; if\ levels\ of\ water\ quality\ each\ parameter\ different\ 3\ levels \end{cases}$$

WQI_5 = Total score of the water quality;
DO = DO or Dissolved Oxygen;
BOD = Biochemical oxygen demand;
FCB = Fecal Coliform Bacteria;
TCB = Total coliforms Bacteria;
NH_3 = Ammoniacal nitrogen;
PS = Different score levels of the water quality with each parameter.

Table 2.2 Score range of WQI_5 with criterion of water quality.

Criterion of water quality	Score WQI_5
Good	71-100
Medium	61-70
Bad	31-60
Very bad	0-30

The current method can be seen as a complex calculations. Difficult for the public to understand Therefore, we propose a simple method to evaluation of water quality. The old method was evaluate the image quality of many experts cause ambiguity Therefore, fuzzy logic is used determine the water quality criteria.

2.2.5 Fuzzy Logic

Fuzzy Logic was initiated in 1965 by L. A. Zadeh [31]-[32]. Fuzzy logic is a logic based on the fact that. Everything in the world of reality is not only what is absolutely only, but there are many things that happen uncertain, unclear and ambiguous.

Boolean or Logic is used to break the boundaries that divide between members and non-members as well. We have drawn a clear distinction between being or not being a member as true or false, 0 or 1, yes or no, etc.

Crisp set or classical set is a set with characterized as Boolean, that the membership only is 0 or 1. The set is sharp boundary that is extent to disengage and clear. It is configured as a member of the binary. The one variable can have only two values of the membership, 0 is non-membership and 1 is membership.

Fuzzy set is a membership to continue. This have membership function which define to either object a level for membership between 0 and 1 [32].

Definition let X is the set of non-empty sets, Fuzzy set A can distinguished by the membership function.

$$\mu_A(x) = U \rightarrow \{0,1\}. \quad (2.3)$$

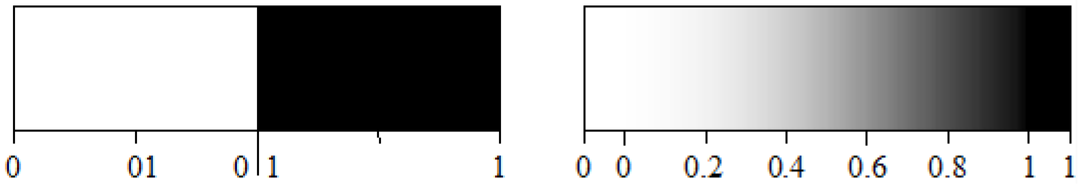
$$A = \{(x, \mu_A(x)) | x \in X\}. \quad (2.4)$$

Where, A instead fuzzy set;

$\mu_A(x)$ instead membership function;

X instead universe.

Comparison between Crisp set and Fuzzy set is shown in Figure 2.1.



(a) Crisp set (b) Fuzzy set

Figure 2.1 value of (a) Crisp set and (b) Fuzzy set.

Table 2.3 Comparison between Crisp set and Fuzzy set.

Weight (kg.)	Crisp set	Fuzzy set
75	1	0.88
60	1	0.72
59	0	0.70
50	0	0.54
38	0	0.03

From the Table 2.3, it is evident that the membership Crisp set to show only two values 0 and 1, if not a member, but if it shows the fuzzy set membership between 0 and 1.

The standard fuzzy set operations are: complement (NOT), intersection (AND), and union (OR). If two fuzzy sets A and B are determine on the universe X, for a given member x belonging to X, the following operations can be carried out:

Union: $$\mu_{A \cup B}(x) = Max(\mu_A(x), \mu_B(x)) \quad (2.5)$$

Intersection: $$\mu_{A \cap B}(x) = Min(\mu_A(x), \mu_B(x)) \quad (2.6)$$

Complement: $$\mu_{\bar{A}}(x) = 1 - \mu_A(x) \quad (2.7)$$

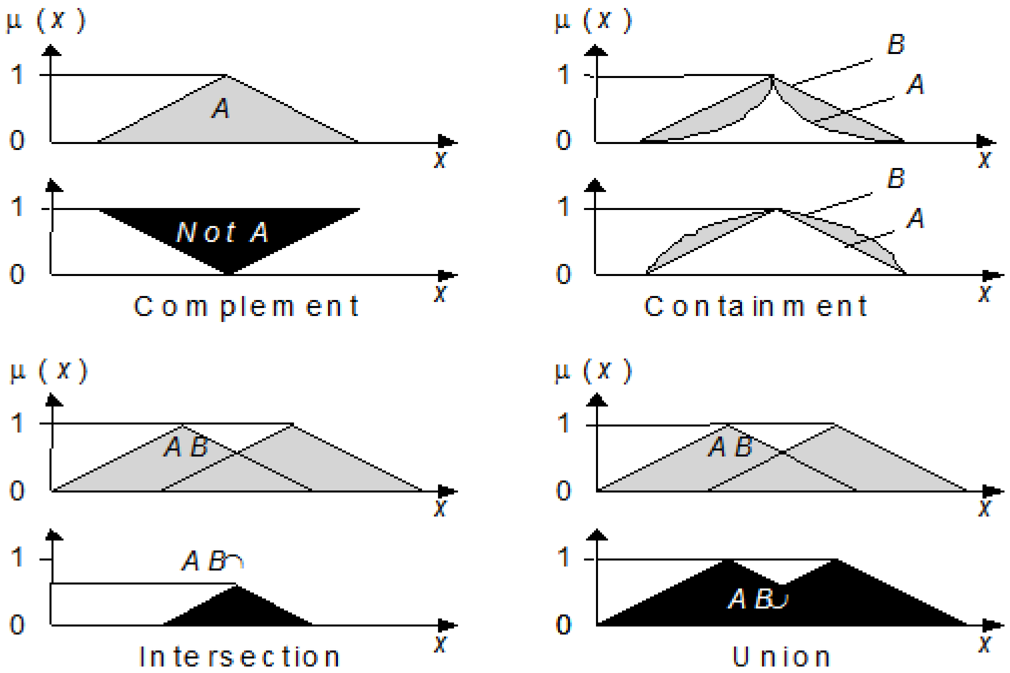


Figure 2.2 Fuzzy set operations.

Membership function is a function that specifies the membership of the variables that need. It is start by replacement the representation with the vagueness, ambiguity and uncertainty as critical to the implementation of fuzzy [10].

- **Type of membership function**

1. Triangular membership function : Triangular curves depend on three parameters *a*, *b*, and *c* and are given by:

$$triangular(x:a,b,c) = \begin{cases} 0 & ,x < a \\ \dfrac{x-a}{b-a} & ,a \le x \le b \\ \dfrac{c-x}{c-b} & ,b \le x \le c \\ 0 & ,x > c \end{cases} \quad (2.8)$$

2. trapezoidal membership function : Trapezoidal curves depend on four parameters and are given by:

$$trapezoidal(x:a,b,c) = \begin{cases} 0 & ,x < a \\ \frac{x-a}{b-a} & ,a \le x \le b \\ 1 & ,b \le x \le c \\ \frac{c-x}{c-b} & ,b \le x \le c \\ 0 & ,x > d \end{cases} \quad (2.9)$$

3. Gaussian membership function **:** Gaussian curves depend on two parameters and are given by:

$$gaussion(x: m, \sigma) = exp\left(-\frac{x-m^2}{\sigma^2}\right) \quad (2.10)$$

4. Bell-shaped membership function : Bell-shaped curves depend on three parameters and are given by:

$$bell - shaped(x: a, b, c) = exp\left(-\frac{x-m^2}{\sigma^2}\right) \quad (2.11)$$

5. Smooth Membership Function : Smooth curves depend on two parameters and are given by:

$$S(x{:}a,b) = \begin{cases} 0 & ,x < a \\ 2\left(\frac{x-a}{b-a}\right)^2 & ,a \le x \le \frac{a+b}{2} \\ 1-2\left(\frac{x-a}{b-a}\right)^2 & ,\frac{a+b}{2} \le x \le b \\ 1 & ,x > b \end{cases} \quad (2.12)$$

6. Z-membership function : Z curves depend on two parameters and are given by:

$$Z(x{:}a,b)=\begin{cases}0 & ,\ x<a\\ 1-2\left(\dfrac{x-b}{b-a}\right)^2 & ,\ a\le x\le \dfrac{a+b}{2}\\ 2\left(\dfrac{x-b}{b-a}\right)^2 & ,\ \dfrac{a+b}{2}\le x\le b\\ 1 & ,\ x>b\end{cases} \quad (2.13)$$

2.2.5.1 Fuzzy inference system (FIS)

The fuzzy inference system (FIS) importantly determines a nonlinear mapping of a vector data input into the scalar output by using fuzzy rules. The mapping processes fuzzification, fuzzy rule evaluation, aggregation and defuzzification**.** The fuzzy inference system with multiple outputs can be discussed as a set of autonomous multiple input [33].

2.2.6 Choose solution method

The current problem is to decide how to resolve the issue of water resources within the working people. That is difficult because of troubleshooting have many alternatives, if the expert decide selection solution of water quality only one person might not be the best alternative therefore must have many experts to decide selection of alternatives. The alternatives for solution because each person have ideas, values and knowledge are different, therefor it is using Group decision of individual rankings multi-criteria method for in order to obtain solution of water quality appropriateness and performance from experts.

2.2.6.1 PROTHEE method

PROTHEE method is analyze of individual rankings. The objective of individual rankings is found a performance and reasonable alternative which is the best conciliate consenting to the point of view everybody of expert related in the decision choose solution of problem. It is important for the learning to standardize and process the knowledge about the problem in group members.

2.2.6.2 PROTHEE II method

PROTHEE II method is individual rankings by a multi-criteria method. This step is to identify the expert obtain and preference for individual evaluation of alternatives. The individual rankings, a multi-criteria method was utilized with each expert individually. Where each expert determined a weight of the criterion for each criterion. Each expert evaluated the relation significance of a criterion and then characteristic coinciding weights of each criteria. The weights are non-negative numbers and total to normalized weights equivalent to 1.

2.2.6.3 Individual Rankings method

The analysis of the individual ranking is processed into 3steps follow as: filter, veto and choose [15].

(a) Filtering phase

The first phase includes of analysis alternatives for the solution of water quality which are the upper and lower quartiles.

$$\text{Upper quartile: } x = n/4. \tag{2.14}$$

$$\text{Lower quartile: } y = (3n/4) + 1. \tag{2.15}$$

Where, x = amount of upper quartile;

y = amount of lower quartile;

n = the total number of alternatives.

(b) Veto phase

The number of locations, consists of alternatives, strength and choice of weakness for the solution of water quality.

$$\text{Strength: } F_i = \sum_{k=1}^{m} \sum_{j=1}^{x} (x - j + 1) q_{ij}^k \qquad \forall i, k \ \ \forall j = 1, 2, .., x \tag{2.16}$$

Where, $$q_{ij}^k = \begin{cases} 1, & \text{if thealternative i is intheposition j for the expert k} \\ 0, & \text{otherwise} \end{cases}$$

$$\text{Weakness: } f_i = \sum_{k=1}^{m} \sum_{j=y}^{x} (j - y + 1) q_{ij}^k \qquad \forall i, k \ \ \forall j = y, .., n \tag{2.17}$$

Where, $$q_{ij}^k = \begin{cases} 1, & \text{if thealternative i is intheposition j for the expert k} \\ 0, & \text{otherwise} \end{cases}$$

On analyze the relationship between the Strength and Weakness of an alternatives, if the weakness more than the strength would be eliminated. The aim of this analysis is to determine whether a conflict is very high. This veto seeks to remove alternatives classified as worst by experts because the weakness rather the strength means alternatives unrelated with problem.

(c) Choosing phase

The alternative for solution of water quality is selected which has the highest number of difference between the Strength and Weakness values, given as:

$$\alpha_i = F_i - f_i. \tag{2.18}$$

The highest α_i is alternative for the solution of water quality, having the best performance and appropriateness.

CHAPTER III
PROPOSED METHODOLOGIES

This study presents a model to create rule in order to divide criterion of water quality using fuzzy logic from 5 indices follows: BOD, DO, FCB, TCB and NH3, which use the data sets collected from the Maekong basin of Thailand. Then use group decision of individual rankings multi-criteria method for solve a problem.

3.1 Data

In Thailand, with water quality indicators of BOD, DO, FCB, TCB and NH3 in the Maekong basin, the data sets are collected from 9 provinces including Tak, Uthaithani, Kanchanaburi, Suphanburi, Nakhonpathom, Ratchaburi, Samutsongkram, Samutsakron and Petchaburi. The data sets have been used from more than 100 sets from 41 sampling stations, which average each year since 2007-2012.

3.2 Proposed Methods

The model creates the rules in order to divide the criterion of water quality and group decision of individual rankings multi-criteria method for solving a problem with 6 steps, as follows: identification of experts, generating model for water quality with fuzzy logic, potential alternatives, selection of criteria for evaluation, application of ranking multi-criteria method, and analysis of individual ranking, as shown in Figure 3.1.

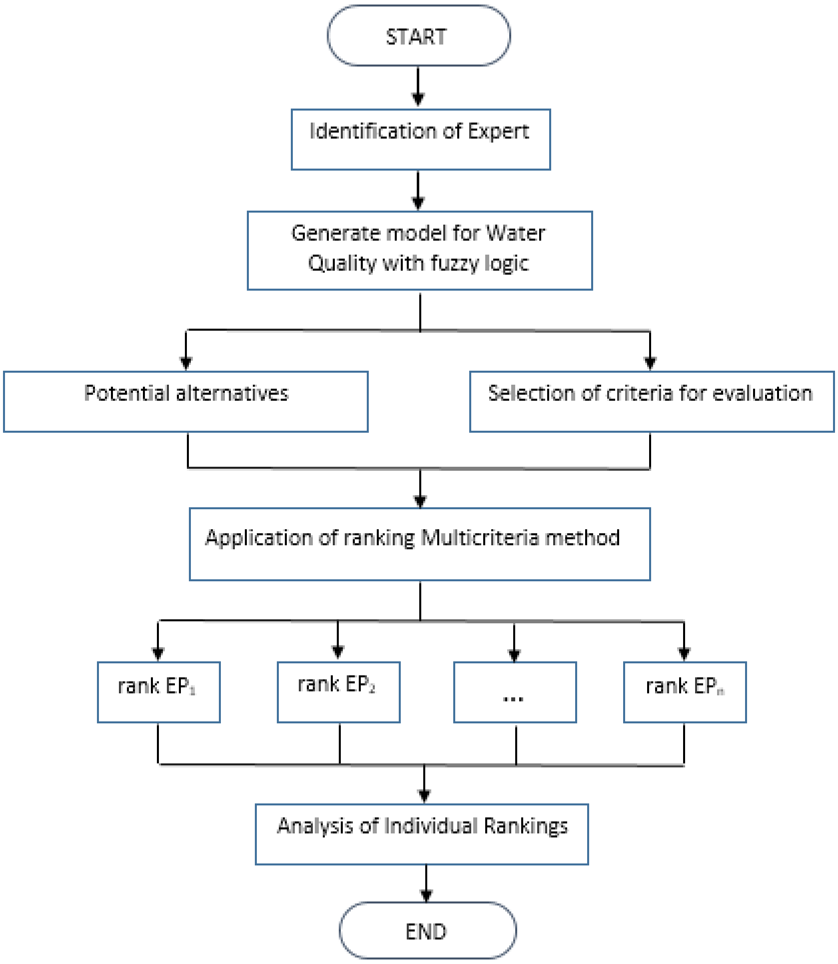


Figure 3.1 The process diagram of water quality classification based on fuzzy rules creation and individual ranking analysis.

3.2.1 Identification of Experts

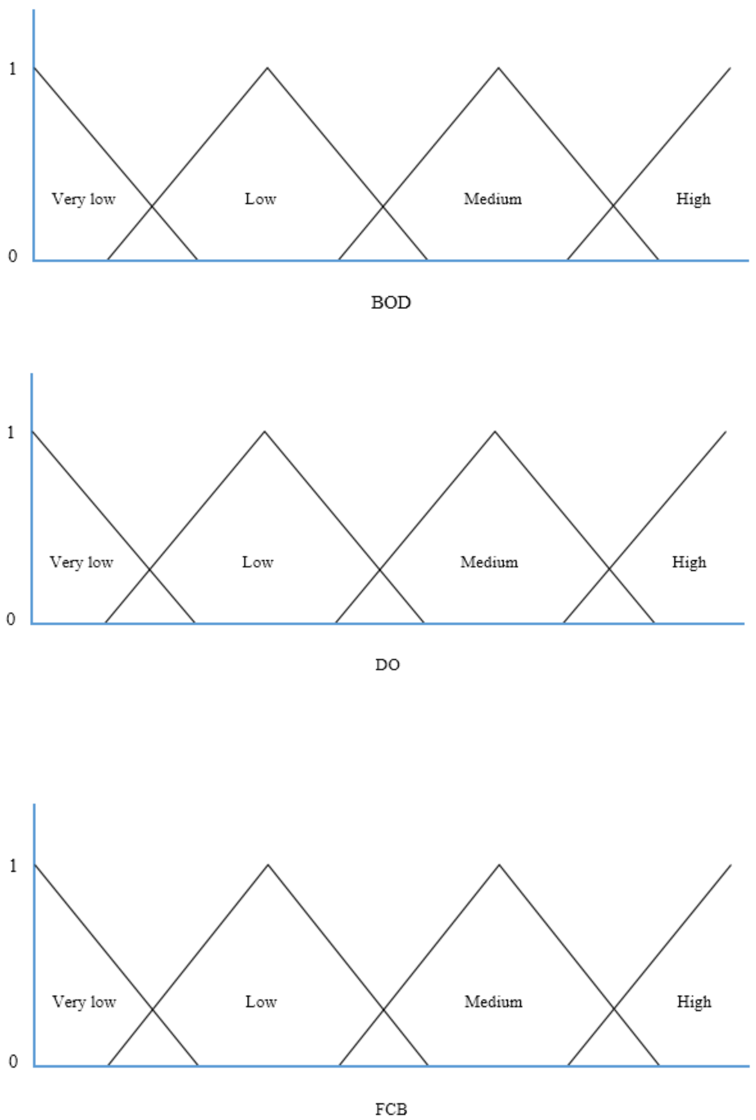
Experts are determined in according with the Strategy or National Policy for water resources management and the cooperation of the process of water resource management. The participator agent public civil, society sector bodies, and users of water resources. Expert might select to only one member from each sector in order to avoid decision of group too large.

3.2.2 Generate model for Water Quality with fuzzy logic

These steps are explained the aim to assign a score of water quality using five indexes: BOD, DO, FCB, TCB and NH3 managed within a fuzzy inference system (FIS). A FIS have 4 steps, as follows: fuzzification, rule evaluation, aggregation, and defuzzification.

3.2.2.1 Fuzzification

The first step is to exchange the parameter value from classical set or crisp set input into fuzzy input by creation membership function. In this case study we use triangular membership function. BOD, DO, FCB, TCB and NH_3 were divided criterion 4 levels are very low, low, medium and high as shown in Figure 3.2.



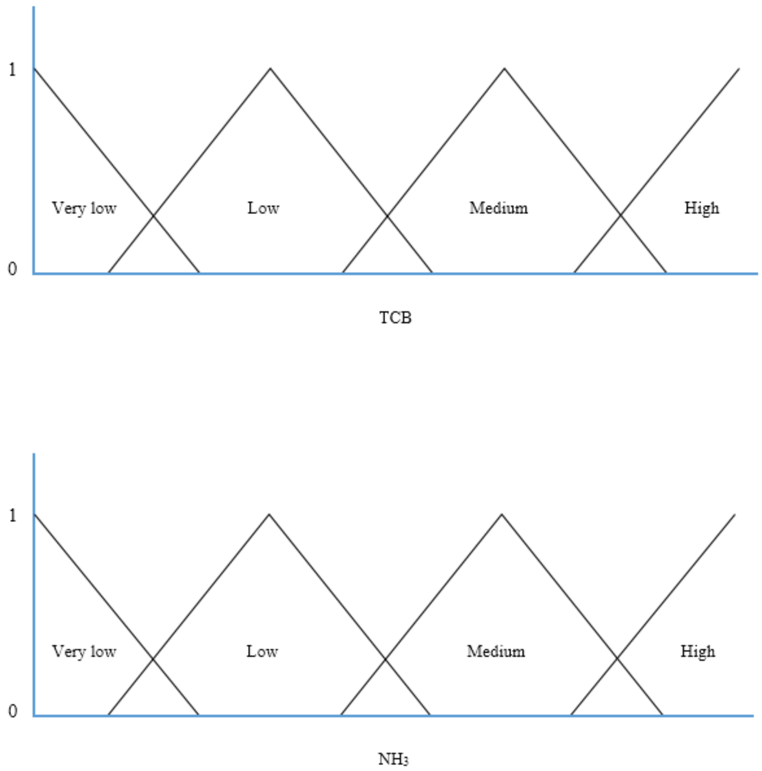


Figure 3.2 Fuzzification: level of water quality each parameters.

3.2.2.2 Rule evaluation

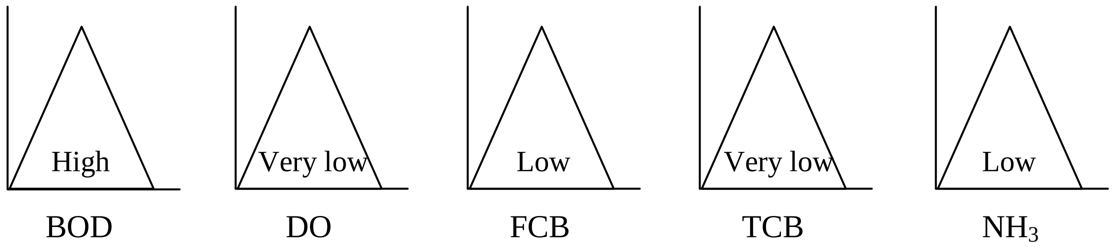
Fuzzy rule evaluation is rule for evaluation levels of water quality, which rule extract the data experts. Fuzzy rule is form IF (condition) THEN (consequent).

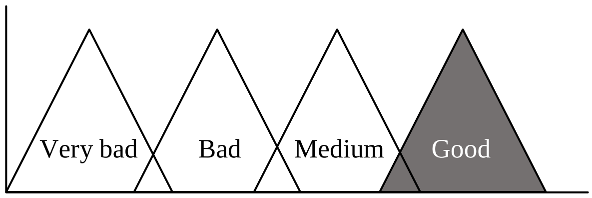
Table 3.1 Rule evaluations of water quality.

Water Quality Indexes	**Levels of Water Quality**			
	High	**Medium**	**Low**	**Very Low**
DO	good	medium	bad	very bad
BOD	bad	bad	medium	good
FCB	bad	medium	good	good
TCB	very bad	bad	medium	good
NH_3	bad	bad	medium	medium

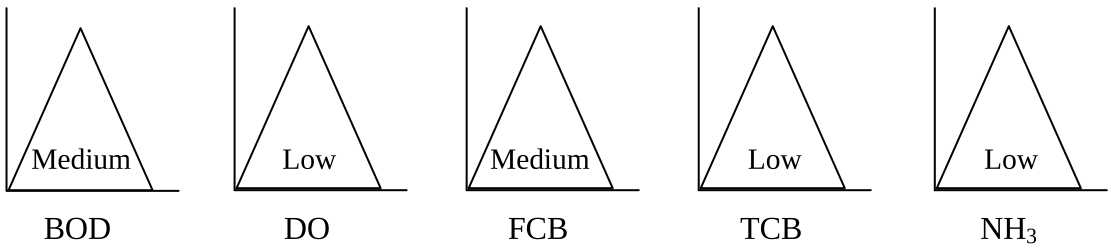
3.2.2.3 Aggregation

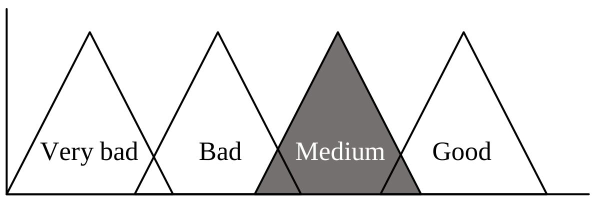
Aggregation is step of unification of output of all rules. Each condition are connected with operation union (∪) that is AND in equation (2.6).



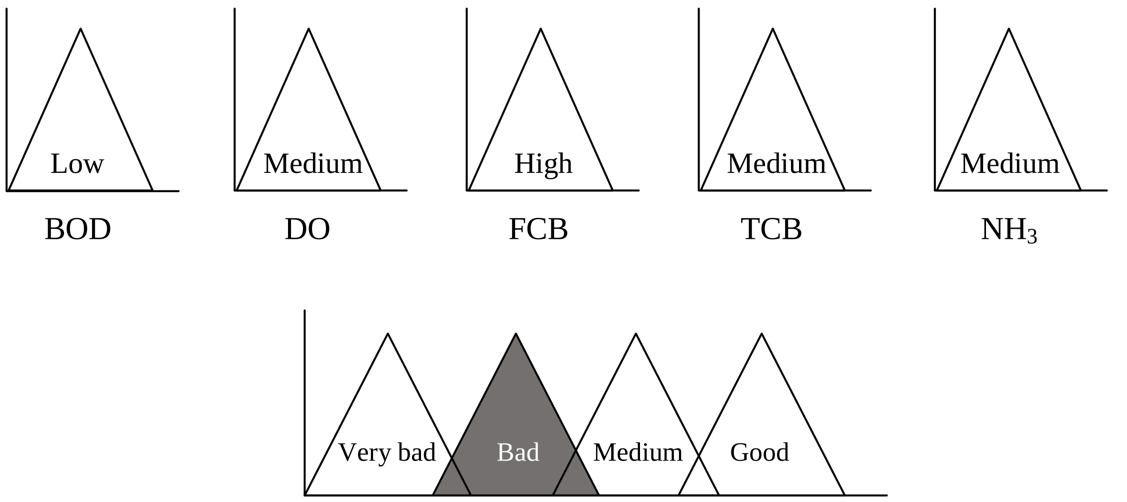


IF (BOD = High) AND (DO = Very low) AND (FCB = Low) AND (TCB = Very low) AND (NH_3 = Low) THEN water quality = Good

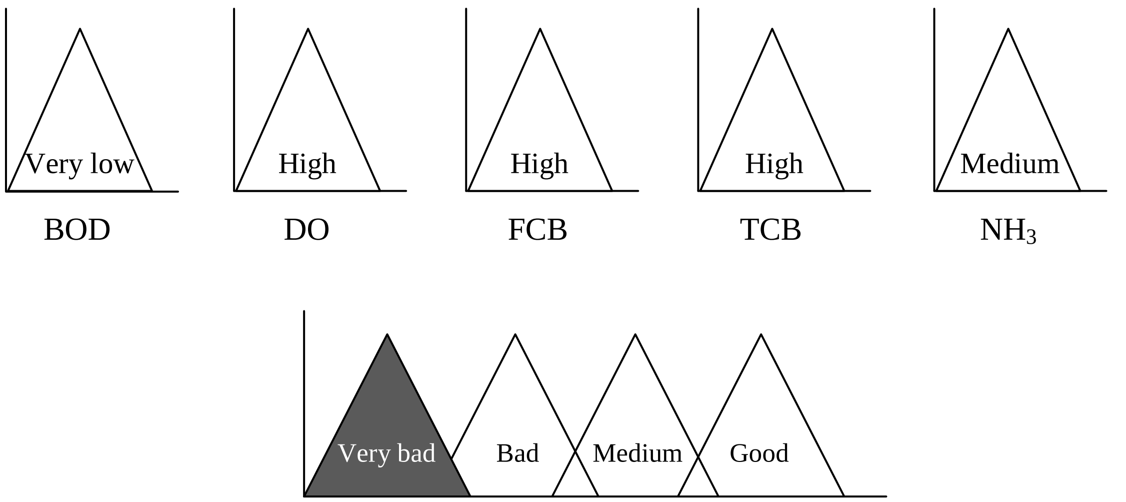




IF (BOD = Medium) AND (DO = Low) AND (FCB = Medium) AND (TCB = Low) AND (NH3 = Low) THEN water quality = Medium



IF (BOD = Low) AND (DO = Medium) AND (FCB = High) AND (TCB = Medium) AND (NH3 = Medium) THEN water quality = Bad



IF (BOD = Very low) AND (DO = High) AND (FCB = High) AND (TCB = High) AND (NH3 = Medium) THEN water quality = Very bad

Figure 3.3 Aggregation of water quality.

3.2.2.4 Defuzzification

Defuzzification is interpreting the membership degrees of the fuzzy output in figure 4 into real value or specific decision.

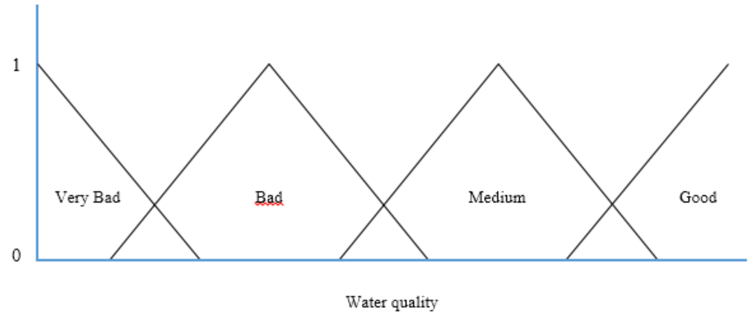


Figure 3.4 Defuzzification: membership degrees of the fuzzy output.

3.2.3 Potential alternatives

Potential alternatives are defined set of alternatives presented in the control or remediation to reduce the impact of the decline of the identified and agreed that they should have fixed the problem in the basin, which chosen by the experts.

3.2.4 Selection of criteria for evaluation

The criterion troubleshooting selection by the experts, evaluation the environmental, social and economic utility of either alternative. The determination of a criterion is operated by the experts in order to assure for appropriateness and performance of participation every experts, by creating at least one criteria for each of them, which display the core interest of them successive entity/sector.

Criteria are considered to include five criterions in order to evaluate the alternatives for with consider to the environmental, economic, financial and social aspects, namely C1: investment value, C2: maintenance costs, C3: dependence on third-parties, C4: industrial impacts, C5: agricultural impacts.

3.2.5 Application of ranking Multi-criteria method

It is individual rankings based on multi-criteria method, which identify the expert preference and receive the individual evaluation of all alternatives by expert determined the weights of the criterion for each alternatives, which sum of all the weights is equal 1.

3.2.6 Rank by expert

The expert voting each alternatives are given by taking the score for a multi-criteria. Then alternatives score is sorted by descending.

3.2.7 Analysis of Individual Rankings

The analysis of the individual priorities is performed in three steps: filter, veto and choose.

3.2.7.1 Filtering phase

The first phase consists of analyzing alternatives for the solution of water quality which are in the upper and lower quartiles in equation (2.14)-(2.15).

3.2.7.2 Veto phase

The positional count is made of the alternatives, the Strength and the Weakness of the alternatives for the solution of water quality in equation (2.16)-(2.17). On analyzing the relation between the Strength and Weakness of the alternatives, if the weakness more than the strength would be eliminated. The analysis to check if there is a very high opposition for alternatives. This veto seeks to eliminate the alternatives classified as worst by the majority of experts because the weakness rather the strength means alternatives unrelated with problem.

3.2.7.3 Choosing phase

The alternative for solution of water quality is selected which has highest number from calculated the Strength and Weakness in equation (2.18). The highest α_i is alternative for the solution of water quality has the best performance and appropriate.

CHAPTER IV
RESULTS AND DISCUSSION

This research have 2 section, the first section is fuzzy rules for criterial division of water quality indicators of BOD, DO, FCB, TCB and NH3 in the Maekong basin. The data sets are collected from 9 provinces including Tak, Uthaithani, Kanchanaburi, Suphanburi, Nakhonpathom, Ratchaburi, Samutsongkram, Samutsakron and Petchaburi. The data sets have been used from more than 100 sets from 41 sampling stations, which average each year since 2007-2012, the second section is choose solution of water quality using Multi-criteria method.

4.1 Result

With the fuzzy rules for evaluation levels of water quality, in this case, experiment have 4 rules, as follows:

- **Rule 1 :** If DO[4.7,6.7] and BOD[0.9,2.7] and TCB [400,4500] and FCB[20,790] and NH_3[0.1,0.3] Then Water quality is Good.
- **Rule 2 :** If DO[4.1,6.2] and BOD[0.9,2.0] and TCB [800,11800] and FCB[110,2000] and NH_3[0.1,0.4] Then Water quality is Medium.
- **Rule 3 :** If DO[3.0,5.9] and BOD[0.8,4.5] and TCB [100,13100] and FCB[10,4100] and NH_3[0.05,0.4] Then Water quality is Bad.
- **Rule 4 :** If DO[1.3,5.2] and BOD[1.7,3.8] and TCB [700,7100] and FCB[130, 3420] and NH_3[0.1,0.9] Then Water quality is Very bad.

The criterion of water quality can be summarized in Table 4.1.

Table 4.1 Criterion of water quality.

Water Quality	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)
Good	4.7-6.7	0.9-2.7	400-4500	20-790	0.1-0.3
Medium	4.1-6.2	0.9-2.0	800-11800	110-2000	0.1-0.4
Bad	3.0-5.9	0.8-4.5	100-13100	10-4100	0.05-0.4
Very bad	1.3-5.2	1.7-3.8	700-7100	130- 3420	0.1-0.9

The solution of water quality have gathered potential alternatives from the basin management plan and develop integrated of Maekong basin, which have 17 alternatives following:

1. Project expansion of wastewater treatment.
2. Project clean a drain in the municipality.
3. Project monitoring water quality in Maekong basin
4. Project clear water in canals
5. Project weeding and garbage in canals
6. Project establishment of volunteer for protect water pollution from the factory.
7. Project educate entrepreneurs for the wastewater and prevention in sewage canals.
8. Project dredging canals to drain.
9. Project Establishment of volunteer water quality monitoring.
10. Project build up grease household.
11. Project install ban garbage in the river and the public.
12. Project contract out cleaning Canal.
13. Project maintenance of water sources reassigned.
14. Project promote environmental conservation
15. Project surveillance on plant emissions, water. And air pollution
16. Project dredging within the district, which has suffered a major impact on the residential consumer public.

17. Purchasing garbage ship in the river.

The experts defined the weights of the criteria for each alternatives in table 4.2

Table 4.2 Weight criteria for evaluation each experts.

Expert No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
EP 1	0.34	0.25	0.25	0.08	0.08
EP 2	0.34	0.25	0.25	0.08	0.08
EP 3	0.25	0.1	0.1	0.2	0.35

The experts take the score of criteria for each alternatives as shown in Tables 4.3-4.5.

Table 4.3 Score alternatives of expert 1.

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
1	17	10	17	5	3
2	12	0	17	1	1
3	13	1	15	10	10
4	8	2	17	15	12
5	15	10	16	5	13
6	8	0	17	17	8
7	6	0	12	17	3

Table 4.3 Score alternatives of expert 1 (cont.)

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
8	17	6	15	13	16
9	5	0	16	17	10
10	7	5	10	0	0
11	17	5	17	5	5
12	17	5	17	3	5
13	10	5	15	0	10
14	12	6	16	0	10
15	15	2	17	17	10
16	17	1	17	11	10
17	17	15	17	10	10

Table 4.4 Score alternatives of expert 2

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
1	15	15	12	10	2
2	13	5	13	5	2
3	10	5	15	13	2
4	10	5	12	12	3
5	12	5	11	5	3
6	15	3	15	10	8
7	10	3	12	10	10

Table 4.4 Score alternatives of expert 2 (cont.)

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
8	20	10	12	10	11
9	8	5	15	15	10
10	10	5	15	5	10
11	8	5	12	5	1
12	19	5	12	3	5
13	10	5	13	5	5
14	10	3	15	5	5
15	19	5	11	10	5
16	18	5	11	13	6
17	20	10	10	10	5

Table 4.5 Score alternatives of expert 3.

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
1	10	5	10	5	5
2	15	10	10	5	5
3	10	15	10	15	15
4	15	10	10	5	10
5	15	10	10	5	10
6	15	5	10	15	5
7	15	5	10	15	5
8	15	10	10	0	5
9	15	5	10	10	10

Table 4.5 Score alternatives of expert 3 (cont.)

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
10	15	15	10	5	5
11	5	5	10	5	5
12	5	10	10	5	10
13	10	15	10	5	15
14	15	5	10	10	10
15	15	5	10	15	0
16	10	5	10	0	5
17	5	5	10	5	10

The expert voting each alternatives are given by taking the score for a multi-criteria. Then alternatives score is sorted by descending as shown in Table 4.6.

Table 4.6 Individual ranking of experts.

Ranking	EP.1	EP.2	EP.3
1	17	8	3
2	8	17	13
3	1	1	4
4	5	15	5
5	11	16	6
6	15	12	7
7	16	6	10
8	12	9	14
9	14	3	9
10	13	10	16

Table 4.6 Individual ranking of experts (cont.)

Ranking	EP.1	EP.2	EP.3
11	4	2	2
12	13	4	12
13	6	7	8
14	2	5	15
15	9	13	1
16	7	14	17
17	10	11	11

After the ranking alternatives from experts with Multi-criteria method, the analysis of the individual priorities are performed in three steps: filter, veto phase (as shown in Table 4.7), and phase choosing (as shown in Table 4.8).

Table 4.7 Upper quartile and Lower quartile

Ranking		EP.1	EP.2	EP.3
1	Upper quartile	17	8	3
2		8	17	13
3		1	1	4
4		5	15	5
14	Lower quartile	2	5	15
15		9	13	1
16		7	14	17
17		10	11	11

Table 4.8 Alternatives for solution of water quality.

Alternative	**Strength(F_i)**	**Weakness(f_i)**	α_i
1	4	3	1
2	0	4	-4
3	4	0	4
4	2	0	2
5	2	4	-2
6	0	0	0
7	0	2	-2
8	7	0	7
9	0	3	-3
10	0	1	-1
11	0	2	-2
12	0	0	0
13	3	3	0
14	0	2	-2
15	1	4	-3
16	0	0	0
17	7	2	5

Project dredging canals to drain in ordering number 8 is a solution of water quality in terms of appropriateness and performance from experts. This is because the alternative solution has the highest gain of the difference between strength and weakness.

4.2 Discussion

From experimental methodology based on neural network, decision tree and fuzzy logic to assess water quality is proposed. Which a methodology based on neural network, decision tree and fuzzy logic have accuracy 69.62 %, 75.48 % and 77.95 % respectively. A methodology based on Fuzzy logic have accuracy more than neural network and decision tree. Therefore, fuzzy logic methodology is suitable in development of effective water management plans as summarized in Table 4.1.

Table 4.9 Comparison of accuracy each methodology.

Method	**Accuracy**
Neural network	69.62 %
Decision tree	75.48 %
Fuzzy	77.95 %

Maekong basin has several problems of poor water quality. The sources of wastewater on Maekong basin are given as: the community, industries, agriculture, and livestock farms. Therefore, individual ranking for solutions of improving water quality should be ranking follow each problem of water quality or each area because it have different value of parameters.

CHAPTER V
CONCLUSION

5.1 Conclusion

This thesis presents a model of fuzzy logic to classify the water quality based on the fuzzy rules in order to divide four criteria of water quality (i.e. good, medium, bad and very bad) from 5 water quality indexes, as follows: BOD, DO, FCB, TCB and NH_3. The data sets, collected from the Maekong basin from 9 provinces including Tak, Uthaithni, Kanchanaburi, Suphanburi, Nakhonpathom, Ratchaburi, Samutsongkram, Samutsakron and Petchaburi, have been used for more than 100 sets from 41 sampling stations. A methodology based on fuzzy logic to creation the fuzzy rule by used process of fuzzy Inference systems, which in case study have 4 rules. Out of compared experiment a methodology based on neural network, decision tree and fuzzy logic, which fuzzy logic had the most accuracy in this case study. A methodology based on fuzzy logic is suitable for developing the effective water management plans. After taking the criterion of water quality, if water quality is not good, we must find out the alternative solutions of water quality. With several troubleshooting, if the selective solution by only one expert might not be the best solution, therefore the solution taken by many experts decision is proposed. This is because persons have differences in ideas, values and knowledge. Therefore, we propose the use of group decision of individual rankings multi-criteria method in order to obtain the appropriate solution of water quality and performance from experts, which the case study is the project of dredging canals to drain.

5.2 Future work

The evaluations levels of water quality should have rule specifically of each provinces or district because in Meakong basin have has several problems of poor water quality with high rank in Thailand. Especially, the sources of wastewater are as follows the community, industries, agriculture, and livestock farms. Therefore criteria of water quality might be different. Which individual ranking for solutions of improving water quality should be ranking follow each problem of water quality or each area because it has different value of parameters.

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APPENDICES

APPENDIX A
DATA USED IN CREATE MODEL

Data used in create model for evaluation water quality

Average year 2012

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
MK01	4.3	1.2	10,450.00	1,697.50	0.2	Medium
MK02	4.7	0.9	17,550.00	1,227.50	0.2	Medium
MK03	4.6	1.5	7,375.00	652.5	0.2	Medium
MK04	4.5	1.2	7,150.00	1,857.50	0.1	Medium
MK05	5.2	1.4	9,550.00	1,052.50	0.1	Medium
MK06	5.3	1.5	35,975.00	3,797.50	0.1	Bad
MK07	5.3	1.4	74,750.00	7,572.50	0.1	Bad
MK07.1	5.4	1.6	61,725.00	5,680.00	0.1	Bad
MK07.9	5.2	1.5	295,750.00	7,082.50	0.1	Bad
MK08	5.6	1.4	40,475.00	4,802.50	0.1	Bad
MK09	5.6	1.4	4,272.50	645	0.1	Medium
MK10	5.5	1.6	3,275.00	827.5	0.2	Medium
KN01	4.5	1.2	18,500	1,433	0.19	Medium
KN02	6	1.1	5,975	308	0.1	Medium
KN2.5	5.3	1	2,600	392.5	0.15	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
KN03	5.7	1.2	1,048	328	0.11	Medium
KN04	4.7	1.3	1,773	263	0.03	Medium
KN4.5	4.3	1.3	1,563	90	0.15	Medium
KN05	3.8	0.9	535	63	0.18	Bad
KY01	4.5	1.3	1,430.00	120.8	0.15	Medium
KY02	4.6	1.5	2,567.50	148.8	0.23	Medium
KY03	4.5	1.3	1,430.00	120.8	0.15	Medium
KY04	3.3	1.5	470	0	0.14	Bad
KY05	3.7	1.4	116.3	10	0.21	Bad
PC01	3.6	5	154,623	42,583	1	Bad
PC02	2.7	2	53,225	8,275	0.88	Bad
PC03	5.4	1.2	33,000	2,975	0.28	Bad
PC04	5.3	1.4	49,975	4,433	0.28	Bad
PC4.1	5.1	0.9	4,100	710	0.3	Medium
PC4.9	5.5	1	1,623	121	0.23	Medium
PC05	5.6	1	673	79	0.3	Medium
PC5.1	5.2	1	2,060	52	0.33	Medium
PC5.9	4.6	1.1	2,300	42	0.38	Medium
PC06	3.5	1	6,250	82	0.35	Medium
PB01	4.5	1.3	2,690.00	284.5	0.2	Medium
PB02	4.3	1.9	10,225.00	250	0.1	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
PB03	3.2	1.1	76,175.00	12,255.00	0.1	Bad
PB04	4.1	1.1	727.5	71.5	0.1	Medium
PB05	5.3	1.4	3,600.00	30.3	0.2	Medium
KB01	4.1	2.5	3,275.00	2,495.00	0.4	Bad
KB02	3	0.8	2,650.00	517.5	0.1	Bad

Average year 2011

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
MK01	4.8	1.1	11,075.00	4,100.00	0.08	Bad
MK02	4.7	1.3	16,725.00	3,875.00	0.1	Medium
MK03	5	2	7,525.00	1,672.50	0.1	Medium
MK04	4.6	1.5	8,550.00	1,760.00	0.1	Medium
MK05	4.6	1.7	8,025.00	677.5	0.1	Medium
MK06	4.6	1.8	63,325.00	2,215.00	0.1	Medium
MK07	5	1.5	20,975.00	2,195.00	0.1	Bad
MK07.1	4.9	1.7	93,150.00	5,050.00	0.3	Bad
MK07.9	4.9	1.7	158,000.00	9,900.00	0.1	Bad
MK08	5.8	1.9	228,250.00	33,700.00	0.2	Bad
MK09	6.2	1.4	837.5	502.5	0.2	Medium
MK10	5.2	1.5	2,560.00	317.5	0.2	Medium
KN01	4.6	1.4	84,125	1,170	0.07	Bad
KN02	5.6	0.7	2,500	431	0.037	Medium
KN2.5	5.6	1.2	5,323	2,158.00	0.15	Medium
KN03	5.9	0.9	2,400	1,105.00	0.037	Medium
KN04	5.3	1.3	3,600	265	0.145	Medium
KN4.5	5.4	1.1	3,620	182	0.2	Medium
KN05	4.3	0.7	815	26	0.3	Medium
KY01	4.6	1.2	1,800.00	168.8	0.27	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
KY02	5	1.2	3,015.00	112.5	0.225	Medium
KY03	4.9	1.4	1,407.50	126.5	0.023	Medium
KY04	4.1	1.3	360	26.7	0.135	Medium
KY05	4.2	1	224	10	0.21	Medium
PC01	5.2	1.7	2,147.50	365	0.56	Very Bad
PC02	4.5	2.6	13,050.00	752.5	0.36	Bad
PC03	4.6	2.4	12,575.00	982.5	0.07	Bad
PC04	4.5	1.1	2,847.50	70	0.13	Medium
PC4.1	5.9	1.5	1,997.50	32.5	0.15	Medium
PC4.9	5.28	0.98	3,950.00	245	0.11	Medium
PC05	5.93	0.9	2,970.00	180	0.1	Medium
PC5.1	6.04	0.9	1,773.00	253	0.16	Good
PC5.9	5.32	0.8	3,483.00	140	0.13	Medium
PC06	4.63	1	6,525.00	2,465.00	0.16	Medium
PB01	5.2	1.7	2,147.50	356	0.3	Medium
PB02	4.5	2.6	13,050.00	752.5	0.2	Bad
PB03	4.6	2.4	12,575.00	982.5	0.2	Bad
PB04	4.5	1.1	2,847.50	70	0.2	Medium
PB05	5.9	1.5	1,997.50	32.5	0.1	Medium
KB01	4.7	4.5	1,407.50	307	0.4	Bad
KB02	3.5	1.2	1,440.00	160	0.1	Bad

Average year 2010

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
MK01	4.6	1.2	11,800.00	2,000.00	0.23	Medium
MK02	4.3	1.2	23050	4747.5	0.2	Bad
MK03	4.3	1.5	4125	1105	0.2	Medium
MK04	4.5	1.9	4850	1210	0.3	Medium
MK05	4.3	1.3	8575	1647.5	0.1	Medium
MK06	4.3	1.8	6800	1480	0.2	Medium
MK07	4.4	1.7	56000	1117.5	0.1	Bad
MK07.1	4.5	2.1	66500	1720	0.2	Bad
MK07.9	4.4	1.6	72750	1850	0.1	Bad
MK08	4.5	1.6	63825	2832.5	0.1	Bad
MK09	5	1.7	525	72	0.1	Good
MK10	4.7	1.3	1822.5	260	0.1	Medium
KN01	4.6	1.6	8,598	3,665	0.05	Medium
KN02	5.4	0.9	920	169	0.058	Medium
KN2.5	4.7	1.3	843	405	0.113	Medium
KN03	5.3	1.2	4,950	933	0.107	Medium
KN04	5.1	1.4	2,358	273	0.197	Medium
KN4.5	3.9	1.2	1,083	60	0	Medium
KN05	4	1.4	830	82	0	Medium
KY01	4.3	1.5	867.5	198.8	0.087	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
KY02	4.8	1.6	1,322.50	62.8	0.058	Medium
KY03	3.9	2.1	582.5	49.8	0.103	Bad
KY04	3.2	1.7	179	50	0.113	Bad
KY05	3.9	1.8	167	10	0.053	Bad
PC01	4.6	5.5	52,000	11,075	0.4	Very Bad
PC02	5	2.9	44,500	3,025	0.3	Bad
PC03	5.4	2	48,850	3,548	0.1	Bad
PC04	5.3	1.6	11,600	1,140	0.1	Medium
PC4.1	5.1	1.5	5,175	2,178	0.1	Medium
PC4.9	6.06	1.25	2,675	63	0.17	Good
PC05	6	1.9	2,440	203	0.2	Medium
PC5.1	6.2	1.7	835	85	0.18	Medium
PC5.9	5.9	2.2	343	134	0.3	Bad
PC06	5.7	1.4	1,203	122	0.4	Medium
PB01	5	1.9	2,207.50	799.5	0.3	Medium
PB02	4.8	3.4	8,550.00	362.5	0.2	Bad
PB03	4.2	1.3	18,722.50	5,380.00	0.1	Medium
PB04	4.5	1.3	1,430.00	27.5	0.1	Medium
PB05	5.6	1.7	1,130.00	58.3	0.1	Medium
KB01	4.2	1.7	7,082.50	532	0.1	Medium
KB02	4.1	1.8	1,072.50	167.5	0.1	Medium

Average year 2009

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
MK01	5.2	0.8	8050	3850	0.2	Medium
MK02	5.3	0.8	10300	3050	0.2	Medium
MK03	5.3	1.4	11300	1725	0.1	Medium
MK04	5.5	1.3	5600	1062.5	0.1	Medium
MK05	5.6	1.5	37275	5522.5	0.1	Bad
MK06	5.7	1.9	24400	13247.5	0.1	Bad
MK07	5.6	1.6	114000	12475	0.1	Bad
MK7.1	5.7	1.7	153075	18447.5	0.2	Bad
MK7.9	5.9	1.2	214475	121075	0.1	Bad
MK08	6	1.3	180500	51307.5	0.2	Bad
MK09	6.1	1.3	378	387.5	0.3	Good
MK10	5.9	1.2	5822.5	612.5	0.1	Medium
KN01	6.1	1.2	10825	1575	0.2	Medium
KN02	5.8	1	3747.5	220.8	0.2	Medium
KN2.5	5.9	1.2	1297.5	695	0.2	Medium
KN03	6.3	1	3097.5	794.5	0.1	Good
KN04	5.8	0.9	2097.5	225	0.1	Medium
KN4.5	6.4	1.1	427.3	152.7	0.1	Good
KN05	5.9	1.2	955	131.3	0.2	Medium
KY01	6.3	1.7	3247.5	122	0.2	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
KY02	6	2.2	2932.5	451.3	0.2	Medium
KY03	6.3	3	5097.5	1919.3	0.1	Medium
KY04	5.8	1.9	1275	15	0.2	Medium
KY05	5.9	2.2	326	32.5	0.2	Medium
PC01	5.8	10.4	10725	28725	0.5	Very Bad
PC02	5.7	2.1	22825	4025	0.4	Bad
PC03	6.5	1.7	18750	3150	0.2	Medium
PC04	5.4	1.1	31725	1597.5	0.1	Bad
PC4.1	6	0.9	10950	712.5	0.2	Medium
PC4.9	5.9	1.7	6375	233.5	0.2	Medium
PC05	6.1	1.3	1630	172.5	0.14	Good
PC5.1	6.7	1.2	927.5	59	0.3	Good
PC5.9	6.5	1.1	1505	87.5	0.1	Good
PC06	6.6	1.9	1232.5	121.3	0.2	Medium
PB01	5.7	1.7	6455	1202.5	0.4	Medium
PB02	5.4	2.4	60697.5	4075	0.2	Bad
PB03	5.8	1.4	20000	1597.5	0.2	Medium
PB04	5.9	1	3072.5	132.5	0.1	Medium
PB05	5.9	1.3	1807.5	179.3	0.14	Medium
KB01	6.1	1.8	7725	1425	0.1	Medium
KB02	6	0.7	13547.5	227.5	0.2	Medium

Average year 2008

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
MK01	5.2	1.1	10,950.00	2,585.00	0.21	Medium
MK02	4.8	1.1	11,700.00	2,925.00	0.18	Medium
MK03	4.5	1.8	5000	1,645.00	0.15	Medium
MK04	4.4	1.8	15,150.00	2,492.50	0.14	Medium
MK05	4.9	2.1	16,000.00	10,422.50	0.2	Bad
MK06	4.6	1.7	21,200.00	14,097.50	0.18	Bad
MK07	5.4	1.7	650,750.00	71,500.00	0.12	Bad
MK7.1	5.5	2.3	208,250.00	30,225.00	0.17	Bad
MK7.9	6.1	2	158,000.00	91,950.00	0.17	Bad
MK08	6.5	2.1	81,350.00	31,200.00	0.13	Bad
MK09	6.2	2.3	1,432.50	305	0.3	Bad
MK10	5.5	1.6	5,907.50	404.5	0.21	Medium
KN01	6	1.2	7,650.00	3,300.00	0.09	Medium
KN02	6.9	1	2,950.00	560	0.08	Good
KN2.5	6.1	1.5	2,710.00	1,010.00	0.13	Medium
KN03	6.5	1.5	6,050.00	775	0.09	Medium
KN04	5.9	1.2	3,350.00	418	0.08	Medium
KN4.5	4.4	1.6	703	107	0.12	Medium
KN05	4.6	2.2	492.5	40.8	0.2	Bad
KY01	5	1.3	3,200.00	347.5	0.14	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
KY02	4.8	1.3	1,562.50	162	0.26	Medium
KY03	5.3	1.9	3,765.00	1,251.30	0.13	Medium
KY04	3	2	1,782.50	19.3	0.09	Medium
KY05	4.4	2	822.5	65	0.13	Medium
PC01	4.4	4.7	31,333.30	15,666.70	0.6	Very bad
PC02	2.9	3.4	38,966.70	21,400.00	0.4	Bad
PC03	5.1	1.7	33,000.00	11,966.70	0.2	Bad
PC04	5.2	2.1	19,666.70	4,366.70	0.3	Bad
PC4.1	4.9	2.7	18,433.30	4,606.70	0.2	Bad
PC4.9	6.2	2	1,596.70	310	0.2	Medium
PC05	6.7	1.4	2,256.70	216.7	0.2	Good
PC5.1	5.6	1.1	10,410.00	396.7	0.3	Medium
PC5.9	5.1	0.9	2,226.00	63.3	0.3	Medium
PC06	4.1	1.3	3,770.00	58.3	0.2	Medium
PB01	4.2	1.5	4,166.70	910	0.3	Medium
PB02	3.5	1.7	4,033.30	823.3	0.3	Bad
PB03	4.5	1.7	14,100.00	3,443.30	0.3	Medium
PB04	5.8	1.1	4,966.70	46	0.3	Medium
PB05	4.7	2.7	4,533.30	20	0.3	Good
KB01	3.7	1.6	3,663.30	917	0.3	Bad
KB02	6.4	1.1	2,330.00	213.3	0.3	Good

Average year 2007

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
MK01	4.1	0.7	15,475.00	2,047.50	0.13	Medium
MK02	4.3	1	7,725.00	1,450.00	0.26	Medium
MK03	4.4	1.9	34,000.00	2,300.00	0.22	Bad
MK04	4.3	2.5	12,500.00	2,600.00	0.2	Bad
MK05	4.8	2.2	16,475.00	5,797.50	0.22	Bad
MK06	5.3	2.3	6,400.00	1,200.00	0.18	Bad
MK07	4.9	2.1	60,000.00	12,850.00	0.22	Bad
MK7.1	5.1	1.9	68,000.00	17,825.00	0.16	Bad
MK7.9	5.1	1.8	106,475.00	22,050.00	0.23	Bad
MK08	5.8	1.9	111,975.00	18,725.00	0.09	Bad
MK09	5.6	2.4	3,607.50	172.5	0.09	Bad
MK10	4.6	1.7	1,350.00	462.5	0.22	Medium
KN01	4.8	1.9	11,975.00	6,225.00	0.24	Bad
KN02	6.3	1.5	3,197.50	717.5	0.18	Good
KN2.5	5.8	2.4	2,175.00	365	0.3	Bad
KN03	6.5	1.4	9,507.50	832.5	0.27	Good
KN04	5.4	1.4	4,375.00	457.5	0.11	Good
KN4.5	3.5	1.8	6,102.50	119.5	0.2	Medium
KN05	4.4	1.7	20,080.00	19,802.50	0.2	Bad
KY01	4.4	1.2	1,550.00	362.5	0.18	Medium

Station	DO (mg/l)	BOD (mg/l)	TCB (MPN/100ml.)	FCB (MPN/100ml)	NH_3 (mg/l)	Water Quality
KY02	4.6	1.6	3,770.00	197.5	0.11	Medium
KY03	4.9	2.4	732.5	104	0.17	Bad
KY04	2.9	2.7	1,417.50	19.3	0.24	Bad
KY05	3.8	2.8	652.5	19	0.13	Bad
PC01	3.6	7.7	1,185,000.0	80,666.70	0.3	Very Bad
PC02	3.7	3.4	25,100.00	13,400.00	0.2	Bad
PC03	7.2	3.1	45,966.70	33,966.70	0.2	Bad
PC04	3.7	3.9	50,100.00	21,100.00	0.2	Bad
PC4.1	5	3.9	4,633.30	966.7	0.2	Bad
PC4.9	5	2.1	5,466.70	1,510.00	0.1	Bad
PC05	5.1	1.8	4,000.00	390	0.2	Medium
PC5.1	5	1.7	1,273.30	636.7	0.1	Medium
PC5.9	4.6	2.4	1,543.30	410	0.1	Bad
PC06	4.4	3.4	1,126.70	91.7	0.2	Bad
PB01	4	2.7	3,833.30	573.3	0.2	Medium
PB02	3.9	2.5	5,800.00	770	0.2	Bad
PB03	5.6	3.2	15,666.70	2,366.70	0.1	Bad
PB04	5.5	1.3	2,366.70	396.7	0.2	Medium
PB05	4.7	2.7	4,566.70	86	0.2	Bad
KB01	5.4	2.7	3,966.70	503.3	0.2	Bad
KB02	5.3	1.6	5,333.30	316.7	0.3	Medium

Data used for choose solution of water quality

Expert 1 is

Weight criteria for evaluation each experts

Expert No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
EP 1	0.34	0.25	0.25	0.08	0.08
EP 2	0.34	0.25	0.25	0.08	0.08
EP 3	0.25	0.1	0.1	0.2	0.35

Score alternatives of expert 1

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
1	17	10	17	5	3
2	12	0	17	1	1
3	13	1	15	10	10
4	8	2	17	15	12
5	15	10	16	5	13
6	8	0	17	17	8
7	6	0	12	17	3
8	17	6	15	13	16
9	5	0	16	17	10
10	7	5	10	0	0
11	17	5	17	5	5
12	17	5	17	3	5
13	10	5	15	0	10
14	12	6	16	0	10
15	15	2	17	17	10
16	17	1	17	11	10
17	17	15	17	10	10

Score alternatives of expert 2

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
1	15	15	12	10	2
2	13	5	13	5	2
3	10	5	15	13	2
4	10	5	12	12	3
5	12	5	11	5	3
6	15	3	15	10	8
7	10	3	12	10	10
8	20	10	12	10	11
9	8	5	15	15	10
10	10	5	15	5	10
11	8	5	12	5	1
12	19	5	12	3	5
13	10	5	13	5	5
14	10	3	15	5	5
15	19	5	11	10	5
16	18	5	11	13	6
17	20	10	10	10	5

Score alternatives of expert 3

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
1	10	5	10	5	5
2	15	10	10	5	5
3	10	15	10	15	15
4	15	10	10	5	10

alternatives No.	investment value	maintenance costs	dependence on third-parties	industrial impacts	Agricul-tural impacts
5	15	10	10	5	10
6	15	5	10	15	5
7	15	5	10	15	5
8	15	10	10	0	5
9	15	5	10	10	10
10	15	15	10	5	5
11	5	5	10	5	5
12	5	10	10	5	10
13	10	15	10	5	15
14	15	5	10	10	10
15	15	5	10	15	0
16	10	5	10	0	5
17	5	5	10	5	10

APPENDIX B
EXPERIMENTAL OUTPUT

Evaluation water quality

Fuzzy logic output

=== Run information ===

Scheme: weka.classifiers.misc.FLR -R 0.5 -Y -B

Relation: DATA

Instances: 179

Attributes: 6

DO

BOD

TCB

FCB

NH3

WQI

Test mode: 5-fold cross-validation

=== Classifier model (full training set) ===

FLR classifier

======================

Rhoa = 0.5

Extracted Rules (Fuzzy Lattices):

Rule: 0 [4.7 6.7] [0.9 2.7] [0.04 0.45] [0.02 0.79] [0.1 0.3] in Class: Good

Rule: 1 [4.1 6.2] [0.9 2.0] [0.08 1.18] [0.11 2.0] [0.1 0.4] in Class: Meduim

Rule: 2 [3.0 5.9] [0.8 4.5] [0.01 1.31] [0.01 4.1] [0.05 0.4] in Class: Bad

Rule: 3 [1.3 5.2] [1.7 3.8] [0.07 0.71] [0.13 3.42] [0.1 0.9] in Class: Very bad

Metric Space:

[1.3 6.7] [0.8 4.5] [0.01 1.31] [0.01 4.1] [0.05 0.9] in Class: Metric Space

Total Number of Rules: 4

Rules pointing in Class Good :1

Rules pointing in Class Meduim :1

Rules pointing in Class Bad :1

Rules pointing in Class Very bad :1

Time taken to build model: 0 seconds

=== Stratified cross-validation ===

=== Summary ===

Correctly Classified Instances	139	77.2152 %
Incorrectly Classified Instances	40	22.7848 %
Kappa statistic	0.6593	
Mean absolute error	0.1139	
Root mean squared error	0.3375	
Relative absolute error	35.7502 %	
Root relative squared error	84.9469 %	
Total Number of Instances	179	

=== Detailed Accuracy By Class ===

TP Rate	FP Rate	Precision	Recall	F-Measure	ROC	Area Class
0.667	0.03	0.8	0.667	0.727	0.818	Good
0.744	0.028	0.97	0.744	0.842	0.858	Medium
0.938	0.238	0.5	0.938	0.652	0.85	Bad
0.75	0	1	0.75	0.857	0.875	Very bad

C4.5 decision tree Stratified cross-validation

Correctly Classified Instances	135	75.4813 %
Incorrectly Classified Instances	44	24.5187 %
Kappa statistic	0.6585	
Mean absolute error	0.1132	
Root mean squared error	0.3369	

Multilayer Perceptron output

Correctly Classified Instances	55	69.6203 %
Incorrectly Classified Instances	24	30.3797 %
Kappa statistic	0.5012	
Mean absolute error	0.1697	
Root mean squared error	0.3482	

Solution water quality

Ranking	Expert1	Expert2	Expert3
1	9	12	14
2	13	11	9
3	12	10	13
4	11	8	5
5	10	5	3
6	8	3	12
7	6	9	11
8	1	13	10
9	2	1	8
10	4	2	1
11	7	6	2
12	14	4	6
13	15	7	15
14	16	15	16
15	5	16	4
16	3	14	7

APPENDIX C

EVALUATION LEVELS OF WATER QUALITY IN MAEKLONG BASIN USING FUZZY LOGIC

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***Abstract*— This the paper presents a model to create rule in order to divide criterion of water quality from 5 indices follows: BOD, DO, FCB, TCB and NH_3 which are divided to criterion of 4 levels i.e. good, medium, bad and very bad. The data sets collected from the Maeklong basin from 9 provinces in Thailand are used more than 200 sets from 41 sampling stations. In the present study, a methodology based on fuzzy logic to assess water quality is proposed. The result from fuzzy logic is that an accuracy is approximately at 89.42%. Therefore, fuzzy logic is a suitable to use a development of effective water management plans.**

Keywords—water quality; fuzzy logic; evaluation levels of water quality;

I. INTRODUCTION

Of all natural resources, water is the most precious and essential. The important factor for survival of all beings in term of consumeration system [1] water after using would be released to water reservoir. Again this mentioned water circulation system causes water pollution problems. And how we could know our water level quality and if the water causes harmful effect to consumer or not?

The number of pollutants compromising the health of river ecosystems can be very attend, depending on the social characteristics and economic of the riverside society beneficiated with the water [2].

Sewage is a wastewater preferred solution or suspension. That is intended to be removed from a community [3]. The acceptability of water quality for its intended use depends on the magnitude of these indicators being often governed by regulations [4] Generally, The Water Quality Indicators (WQI) used to evaluate water quality. WQI is obtained by adding the multiplication of the specific weight factor by an appropriated quality-value for each parameter. The WQI index consists of nine parameters as follows: biochemical oxygen demand (0.11), dissolved oxygen (0.17), faecal coliforms (0.16), nitrates (0.10), pH (0.11), temperature change (0.1), phosphates (0.10), total solids (0.07) and turbidity (0.08). In parentheses are given the weight factors according to the importance of the indicators. Other indices are also used at regional level to evaluate water quality [5]. However WQI appropriate to overview of water quality in riverhead [6]. In the present, study only water quality index 5 indices as follows: BOD, DO, FCB, TCB and NH_3, which appropriate to overview of water quality in riverhead was in the acceptable expert [7].

Because of DO or Dissolved Oxygen is amount of gaseous oxygen dissolved present in water. It is an important parameter in evaluating water quality because of its influence on the organisms living within a body of water. A DO level that is too low or too high can harm aquatic life and affect water quality [8].

BOD or Biochemical oxygen demand is amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic matter present in a given water example at certain temperature over a specific time period. It is widely used as an indication of the organic quality of water [9].

FCB or Fecal Coliform Bacteria in aqueous environments may indicate that the water has been contaminated with the fecal material of other animals or humans. FCB can enter rivers through direct discharge of waste from mammals and birds, from storm runoff, agricultural and from human sewage [10].

TCB Total coliforms Bacteria are a group of bacteria commonly found in the environment, for sample in vegetation or soil, as well as the intestines of mammals, including humans. TCB are not likely to cause illness, but their presence indicates that your water supply may be vulnerable to contamination by more harmful microorganisms [11].

And NH_3 or Ammoniacal nitrogen (NH_3-N), is a measure for the amount of ammonia, a toxic pollutant often found in landfill leachate[12] and in waste products, such as sewage, and other liquid organic waste products[13]. It can also be used as a measure of the health of water in natural bodies such as rivers, lakes and in water reservoirs [14].

This case study tested methodology based on neural network, decision tree, expert of the pollution center department in Thailand and fuzzy logic, which a methodology based on Fuzzy logic have accuracy more than methodology based on Neural network and Decision tree. For this reason, this research selected classification for Evaluate water quality with methodology based on fuzzy logic

Aforementioned, some alternative methodologies have emerged from artificial intelligence. These methodologies, mainly fuzzy logic and fuzzy sets, are being tested with real environmental problems. The final aim is to reduce the imprecision and uncertainty in criteria employed in decision-making tools [15]-[17]. Each specialist experts has their own concepts, values and all different holistic knowledge in order to gain standard in water quality measurement at the most suitable manner. So fuzzy logic method would be used for classified to divided criterion water quality.

I. METHOD

A. Study area

The data set collected from the Maeklong basin in 9 provinces in Thailand has been used from more than 200 sets from 41 sampling stations, which average each year since 2010-2012.

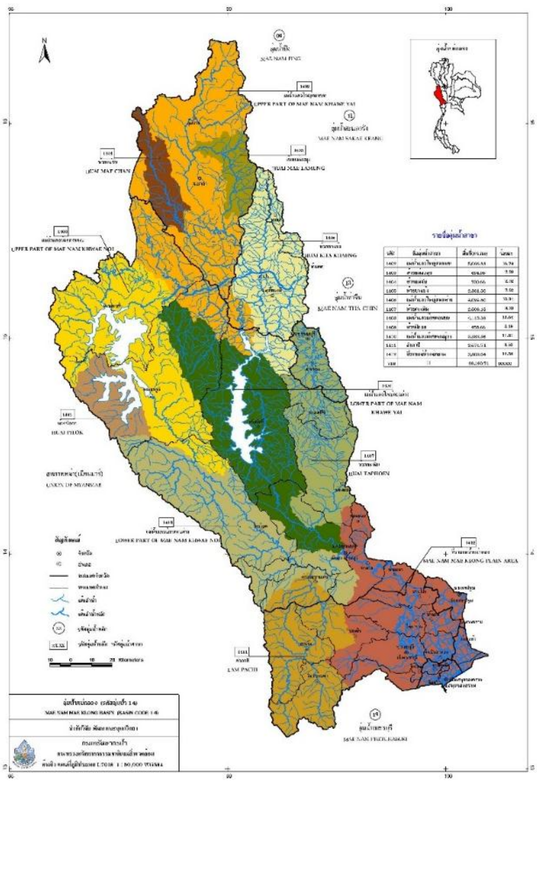
Maeklong basin (shown in Figure1) locates at the West of Thailand. This river is important basin in The Middle part of Thailand as well. The river starts from Trak provice and flowing through South part until Samutsongkram province. At the West part is high mountain area which is near and close to Mynmar. East part is close to Thachine river and south part is close to Petchaburi river and Thai basin. River basin area is around 30,836 square kilometers. The majority river are Maekong river which is divided into 2 branches. They are Meanam Khae Yai and Meanam Khae Noi that convers at Maung Kanchanaburi province. So this comes to be Maeklong that flows to south east part passing through Ratchaburi province and ending at Thai Basin at Samutsongkram province. Total distance is around 143 kilometers dividing into 3 parts. In order to solve relating province with area conditions:

1) Watershed forest area for Maeklong river locates in four provinces area .They are Suphunburi province, Uthai Thanee Province, Tak Province and Kanchanaburi Province with total area at 21,873 square kilometers.

2) Area communities and agricultural areas is basin plain structure from the middle of the river down to the bottom. Before Maeklong flow into the delta bank area of the river. And coast areas is in 3 provinces: Kanchanaburi province, Nakhonpathom province and Ratchaburi province with total area at 8,033 square kilometers.

3) Delta and coast area receives influence from sea water with delta ecosystem that locates in 4 areas. They are Ratchaburi province, Petchaburi province, Samutsongkram province and Samutsakorn province [18].

Fig. 1. The map of Maeklong basin



B. Fuzzy logic

Fuzzy logic is an ambiguous. It deals with reasoning that is approximate rather than fixed and definite. Compared to traditional binary sets, which variables may take on true or false, or 0 or 1 values only, but fuzzy logic variables may have a truth value that ranges in degree between 0 to 1. Fuzzy logic has been developed to handle the concept of partial truth, where the truth value may range between completely true and completely false [19].

A fuzzy set is a class of objects with continue of levels of membership. It is characterized by a membership function which assigns to each object a levels of membership ranging between zero and one [20].

The standard fuzzy set operations are: union (OR), intersection (AND) and complement (NOT). They manage the essence of fuzzy logic. If two fuzzy sets A and B are defined on the universe X, for a given element x belonging to X, the following operations can be carried out:

Union: $\mu_{A\cup B}(x) = Max(\mu_A(x), \mu_B(x))$ (1)

Intersection:

$$\mu_{A\cap B}(x) = Min(\mu_A(x), \mu_B(x)) \quad (2)$$

Complement: $\mu_{\bar{A}}(x) = 1 - \mu_A(x)$ (3)

In the present study is used Triangular function: Have 3 parameters defined by a lower limit a, an upper limit b, and a value m, where a < m < b.

$$\mu_A(x) = \begin{cases} 0 & , x < a \\ \dfrac{x-a}{b-a} & , a \le x \le b \\ \dfrac{c-x}{c-b} & , b \le x \le c \\ 0 & , x > c \end{cases} \quad (4)$$

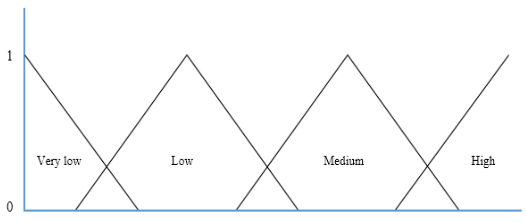
Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. This mapping provides a basis from which decisions can be made [21].

Fuzzy inference system (FIS) can be divided into four steps are fuzzification, fuzzy rule evaluation, aggregation and defuzzification. These steps are explained with the following example, in which the aim has been to assign a water quality score using just five variables: BOD, DO, FCB, TCB and NH_3 managed within a FIS.

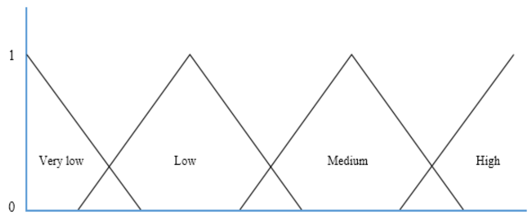
Process of fuzzy Inference systems

These steps are explained with the following example, in which the aim has been to assign a water quality score using just five variables: BOD, DO, FCB, TCB and NH_3 managed within a FIS. A fuzzy inference system (FIS) can be divided into four steps are fuzzification, fuzzy rule evaluation, aggregation and defuzzification.

- **Fuzzification** is step for exchange parameter value from classical set or crisp set input into fuzzy input by creation membership function which, this case study using triangular membership function in equation (4). BOD, DO, FCB, TCB and NH_3 were divided criterion 4 levels are very low, low, medium and high as shown in figure 2.
- **Fuzzy rule evaluation** is rule for evaluation levels of water quality, which rule extracted data mining. Fuzzy rule is form IF (condition) THEN (consequent(which, each condition are connected with operation intersection ($\cap$) that is AND in equation (2).
- **Aggregation** is step of unification of output of all rules which, each condition are connected with operation union ($\cup$) that is OR in equation (1).
- **Defuzzification** is interpreting the membership degrees of the fuzzy output in figure 3 into real value or specific decision.



BOD



DO

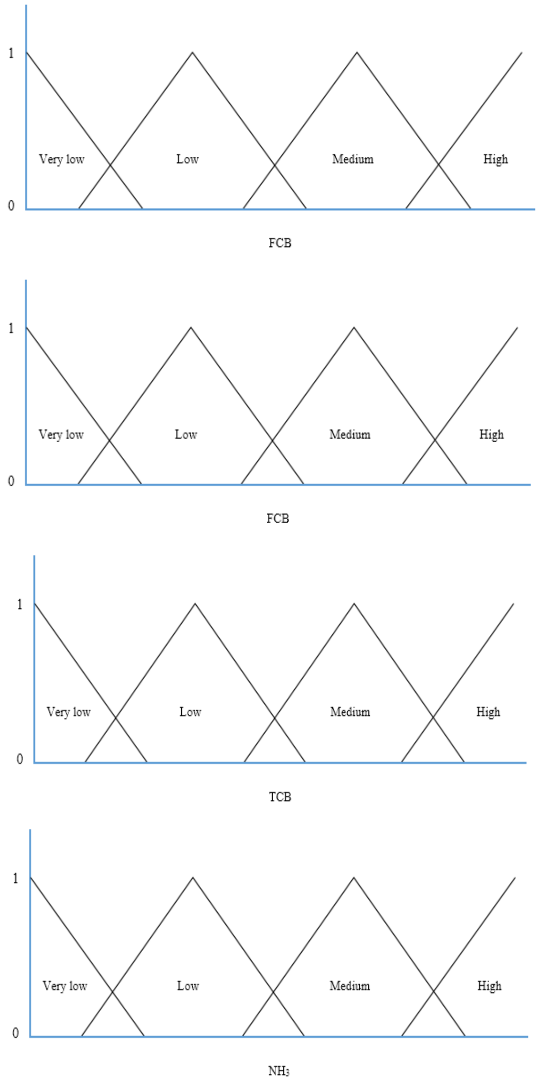


Fig. 2. Fuzzification: level of water quality each parameters

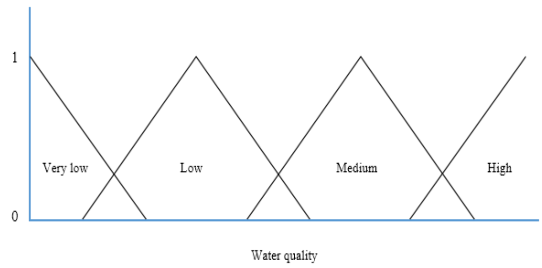


Fig. 3. Fuzzification: levels of water quality

III. EXPERIMENTAL RESULTS

In the case study, a data set collected from the Maeklong basin from 9 provinces in Thailand has been used from more than 200 sets from 41 sampling stations, which average each year since 2010-2012 using a methodology based on neural network, decision tree and fuzzy logic to assess water quality is proposed. Which a methodology based on neural network, decision tree and fuzzy logic have accuracy 79.71 %, 88.78 % and 89.42 % respectively. A methodology based on Fuzzy logic have accuracy more than neural network and decision tree. Therefrom, compare fuzzy logic and a methodology expert of the pollution center department in Thailand, which it is has accuracy 88.89%. Therefore, fuzzy logic methodology as a suitable to be used in developing effective water management plans as summarized in Table I.

TABLE I. COMPARISON OF ACCURACY EACH METHODOLOGY

Method	Accuracy
Fuzzy	89.42 %
Neural network	79.71 %
Decision tree	88.78 %
Expert (Pollution center department in Thailand)	88.89%

Fuzzy rule for evaluation level of water quality**.** In this case experiment have 4 rules following

- **Rule 1 :** If DO[4.7,6.7] and BOD[0.9,2.7] and TCB [400,4500] and FCB[20, 790] and NH_3[0.1,0.3] Then Water quality is Good.
- **Rule 2 :** If DO[4.1,6.2] and BOD[0.9,2.0] and TCB q[800,11800] and FCB[110,2000] and NH_3[0.1,0.4] Then Water quality is Medium.
- **Rule 3 :** If DO[3.0,5.9] and BOD[0.8,4.5] and TCB [100,13100] and FCB[10,4100] and NH_3[0.05,0.4] Then Water quality is Bad.
- **Rule 4 :** If DO[1.3,5.2] and BOD[1.7,3.8] and TCB [700,7100] and FCB[130, 3420] and NH_3[0.1,0.9] Then Water quality is Very bad.

IV. Conclusions

This paper presents a model for evaluation levels of water quality in Maeklong basin which the parameters are BOD, DO, FCB, TCB and NH_3 with divide water quality criterion 4 levels are Good, medium, bad and very bad which, the data set collected from the Maeklong basin from 9 provinces in Thailand has been used more than 200 sets from 41 sampling stations. A methodology based on fuzzy logic to creation the fuzzy rule by used Process of fuzzy Inference systems, which in case study have 4 rules. Out of compared experiment a methodology based on neural network, decision tree, expert of the pollution center department in Thailand and fuzzy logic, which fuzzy logic had the most accuracy in this case study. A methodology based on fuzzy logic as a suitable to be used in developing effective water management plans.

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PUBLICATION / PRESENTATION	BMEiCON-2014 (November 25-27, 2014) (Evaluation Levels of Water Quality in Maeklong Basin Using Fuzzy Logic)